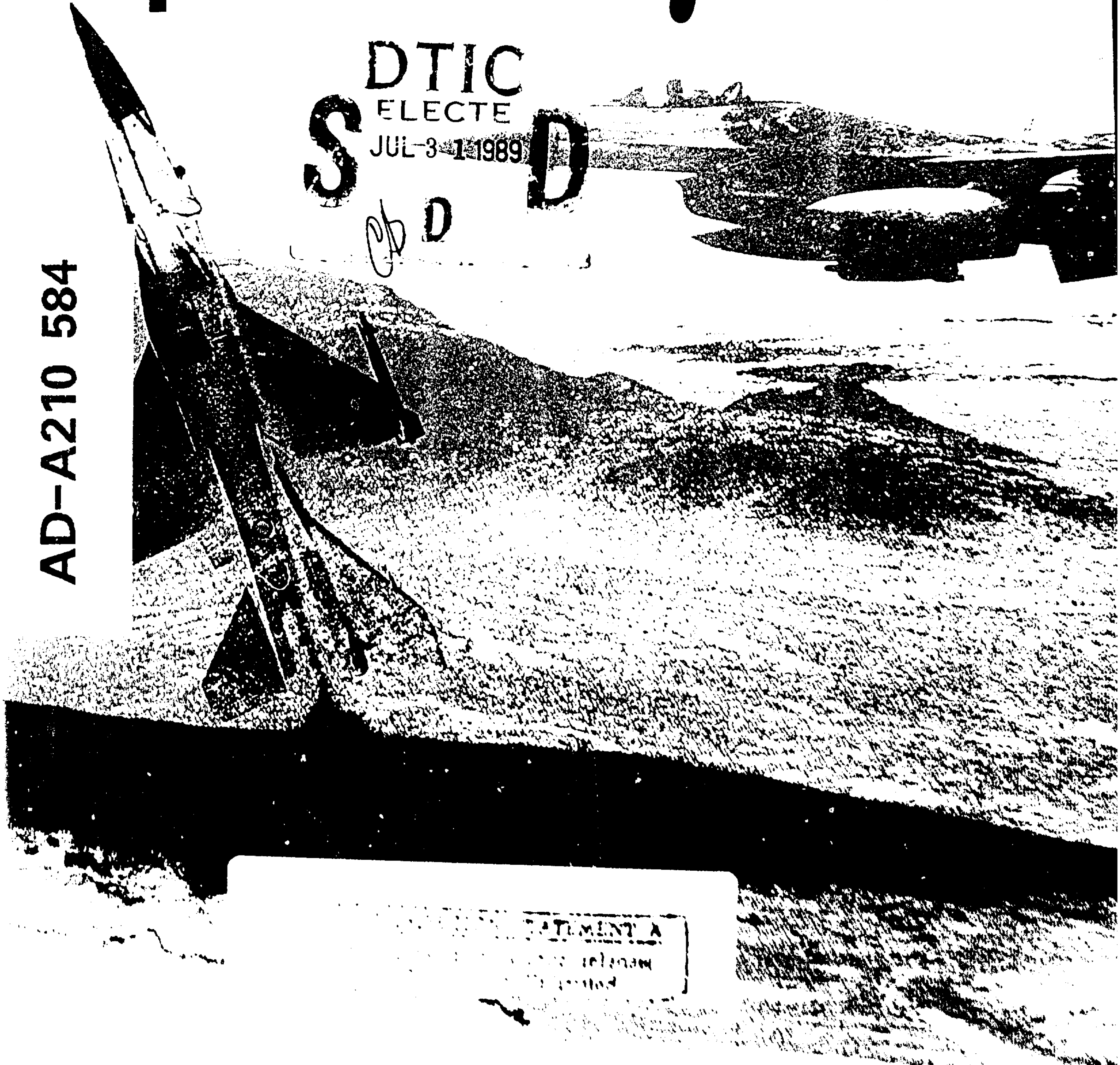
July-August 1989

PROGRAM manager



Journal of the Defense Systems Management College

PROGRAM Manager

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Program Manager (ISSN 0199-7114) is published bimonthly by the Defense Systems Management College, Fort Belvoir, VA 22060-5426. Non-government employees and organizations may subscribe at $7.50 annually through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Second class postage paid at Fort Belvoir, VA.

POSTMASTER: Send address changes to *Program Manager*, Defense Systems Management College, Fort Belvoir, VA 22060-5426.

Vol. XVIII, No. 4, DSMC 91

Also

Cover: Technology in the USAF F-16C Fighting Falcon was chosen as the basis for the proposed Japanese FSX. These planes are in this issue's cover design. The FSX would include an improved engine, aerodynamic modifications and an advanced avionics and weapon system package.

Whenever in this publication "man," "men," or their related pronouns appear, either as words or parts of words (other than with obvious reference to named male individuals), they have been used for literary purposes and are meant in their generic sense.

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Washington, D.C. 20402

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THE FSX DEBATE: IMPLICATIONS FOR FUTURE U.S. INTERNATIONAL ARMAMENTS PROGRAMS

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A great debate has risen over the joint program between the United States and Japan to develop the next-generation fighter aircraft for the Japanese Air Self-Defense Forces. This aircraft, dubbed the FSX (Fighter Support-Experimental, also abbreviated as FS-X), would be a derivative of America's F-16 fighter. The U.S. Departments of Defense and State have aligned in favor of this cooperative program. However, certain members of the Congress, as well as the Department of Commerce, have criticized the program and have been maneuvering to prevent its approval. The focus of the debate centers on issues such as the health of the defense industrial base, protection of technology, trade balances and international security relationships. This scrutiny of the program portends more than just the fate of 130 aircraft for Japan. Of greater significance is the implication such review holds for the future of U.S. international cooperative programs.

FSX History

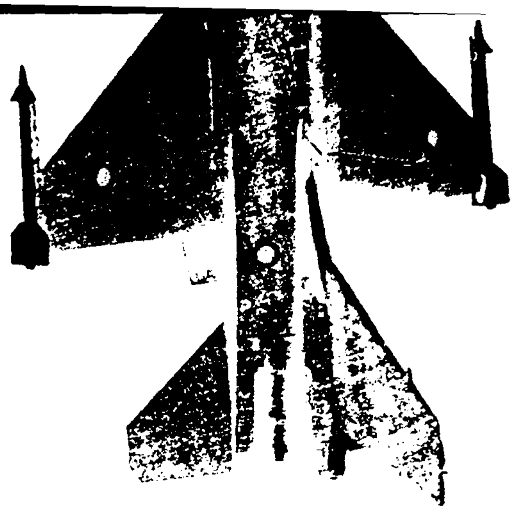
Direction for the FSX program is rooted in Japan's Mid-Term Defense Program (MTDP) adopted in 1985. It states that the FSX "will be selected among three options: first, domestic development; second, conversion of fighters in the inventory; third, introduction of foreign aircraft."[1] However, the conversion of existing fighters in Japan's inventory was dismissed rather early. Because of plans to modify many of the Japanese aircraft for other roles such as reconnaissance, too few eligible fighters would be left to fill a support fighter role. Consequently, the early options for the FSX narrowed to domestic development in Japan or purchase of existing foreign aircraft.

Of these two remaining options, serious debate was directed toward the appropriate path for the FSX. Richard J. Samuel and Benjamin C. Whipple of the Massachusetts Institute of Technology chronicled the debate in Japan:

> Private industry, the JDA's [Japanese Defense Agency] Technical Research and Development Institute (TRDI) and Air Staff Office, and MITI's [Ministry of International Trade and Industry] Aircraft and Ordinance Office, were the most active proponents of domestic development, while MITI's Trade Bureau and JDA Budget officials were opposed. Finance and Foreign Ministry officials concerned with budgets and U.S.-Japanese relations were reported to be cautious or opposed. The other ministries were united in opposition and were joined by Japan's perennial opposition parties.[2]

These same sources reported that the depth of the original opposition to domestic development of the FSX would have dictated that Japan purchase a foreign aircraft to fill the role. However, a Service Life Extension Program for the aging F-1's [the plane the FSX is to replace] provided proponents of domestic development with a strategic delay that was to alter the debate over domestic development versus foreign purchase. Essentially, the active life of the F-1 was extended by at least 4 years, and:

> Due to the life extensions of the F-1's, replacement of them will begin four years later than originally planned (from the late '80's to the 1990's). This delay will leave enough time to develop [the] FSX.[3]



When the FSX debate resumed in Japan in 1985, proponents were able to address the issue from a much stronger position. Five developments in the interlude strengthened the domestic development argument:

1) Ambitious military aircraft programs were conducted in the 1980s which nurtured the capabilities of the Japanese aerospace industry. Consequently, proponents were able to argue that Japanese industry was ready to produce an indigenous fighter—an argument which was not convincing prior to these aircraft programs.

2) The role of the FSX expanded to fulfill several missions, thereby boosting the economics of the program.

3) The later deployment of the FSX produced the argument that foreign candidates would be technologically obsolete.

4) Industry and government in Japan embraced the idea of promoting dual use technology.

5) The need to redirect heavy industry in Japan, as well as disenchantment with international cooperative programs vis-a-vis the faltering 7J7 and IAE programs, strengthened the domestic development cause.[4]

The result was that "when the FSX decision was finally made, domestic opposition to domestic development had largely withered away, and only U. S. pressure, amplified by the Toshiba incident, remained a significant obstacle"[5]

The U. S. companies such as General Dynamics and McDonnell Douglas had been vigorously marketing their off-the-shelf fighters to Japan for years. In November of 1985 Japan issued a questionnaire to these companies for Foreign Military Sales and license data on the F-16 and F-18 aircraft.[6] This inquiry was supported by Japanese opponents of domestic development of the FSX. However, as documented above, the domestic development argument in Japan had been strengthened and this coincided with the emergence of official U. S. pressure to buy American.

The Defense Security Assistance Agency (DSAA), along with DOD and State Department representatives, embarked upon earnest negotiations in 1985 with the Japanese for a U. S. role in the FSX program. The United States "pushed a straight, off-the-shelf purchase of U. S. aircraft as hard as you could push it," stated a DSAA official involved in the negotiations.[7] However, this option was never a creditable one in the opinion of those involved:

> An "off-the-shelf" purchase of a U. S. fighter was never a realistic possibility. Since 1955, under a policy endorsed by every Administration since Eisenhower, Japan has license-produced U. S. military aircraft. General Dynamics, maker of the F-16, tried 12 years without success to sell F-16s to the Japanese Defense Agency.[8]

With the removal of Japanese purchase of U.S. aircraft as an option for the FSX, U.S. efforts turned toward dissuading the Japanese from embarking on an indigenous development route. The U.S. case against Japanese domestic development centered on the following arguments:

1) Japanese indigenous development of the FSX would not be cost effective. Starting "from scratch" would consume valuable resources.

2) The final product of such development would, in the U.S. opinion, be inferior to existing U.S. aircraft and be fielded too late.

3) Domestic development would not embrace the defense cooperation principles developed through the history of the U.S.-Japanese security relationship.

4) An all-Japanese aircraft would not be interoperable with U.S. forces.

5) American industry would have been excluded from the project, further aggravating a growing trade deficit with Japan.[9]

This pressure from the United States culminated with the discussions in early 1987 between then-Secretary of Defense Caspar Weinberger and Japanese Defense Agency Director General Kurihara Yuko. It was at this point, after long and intense negotiations, that the two governments agreed to a modified U.S. fighter for the FSX role rather than an indigenous Japanese aircraft.

> In October 1987, Director-General Kurihara Yuko of the Japanese Defense Agency announced *that Japan would forego* domestic development of the FS-X and instead spend $6 billion procuring a "lightly modified" American aircraft.[10]

The Japanese subsequently chose the General Dynamics F-16C as the basis for the FSX. Additionally, Mitsubishi Heavy Industries was selected as the prime contractor with General Dynamics, Fuji Heavy Industries and Kawasaki Heavy Industries serving as subcontractors. The formal Memorandum of Understanding (MOU) for the FSX was signed November 29, 1988, by Japanese Defense Agency Bureau of Equipment head Masaji Yamamoto and DSAA Director Lieutenant General Charles Brown. The MOU broadly outlined the FSX agreement, establishing that Japan would completely fund the program, that FSX technology would flow back to the United States and that the Japanese Defense Agency would chart the development of the FSX in close consultation with the United States. However, specific technology transfer issues and the U.S. workshare were left for later negotiations.

WORLDWIDE INVENTORY OF F-16 A/B/C/D AIRCRAFT

	A	B	C	D	TOTAL
USAF	597	109	556	77	1339
BELGIUM	90	19	0	0	109
DENMARK	44	14	0	0	58
NORWAY	54	11	0	0	65
THE NETHERLANDS	124	33	0	0	157
ISRAEL	58	6	51	24	139
EGYPT	33	7	34	6	80
PAKISTAN	27	11	0	0	38
VENEZUELA	18	6	0	0	24
KOREA	0	0	30	6	36
TURKEY	0	0	17	6	23
SINGAPORE	4	4	0	0	8
THAILAND	8	4	0	0	12
INDONESIA	0	0	0	0	0
BAHRAIN	0	0	0	0	0
GREECE	0	0	3	5	8
US NAVY	0	0	22	4	26
TOTAL	1057	224	713	128	2122

*EXCLUDED ATTRITED AIRCRAFT

These two issues left out of the MOU, specific technology transfer and the workshare, proved to be the focus of intense negotiations following the signing of the MOU. Much of the disagreement focused on the FSX wings. These were to be developed utilizing Japanese composite technology. Mitsubishi was willing to transfer the technology, but insisted the wings be built in Japan. However, the United States felt that for effective transfer of the technology, that General Dynamics would have to construct full wings in its U.S. facilities.[11] In addition, the MOU merely stated that total U.S. workshare of the FSX would be between 35 and 45 percent, which was the compromise reached in June of 1988 by Secretary of Defense Carlucci and then-Director General of the Japanese Defense Agency Tsutomu Kawara.[12] The U.S. negotiators were intent on "nailing down" the specific workshare, and ensuring that it was a quality contribution. By mid-January of 1989, these issues were resolved. The two sides agreed that the wings of two of the seven prototype aircraft would be built in the United States. In addition, negotiators settled on a 40 percent workshare for the United States, based on a task-based division of the development work, thereby ensuring that the American share is composed of quality work.[13]

The License and Technical Assistance Agreement (LTAA) between General Dynamics and Mitsubishi was signed January 12, 1989. This agreement formalized and established the relationship between the two companies on the FSX program. The next step was for the Bush Administration to notify the Congress of its intent to approve a commercial manufacturing license for Japan, in accordance with section 36 of the Arms Export Control Act. The Congress would be allowed to review the export license application for the F-16 data to be transferred to Japan. This notification was expected by January 31, 1989. However, notification was suspended due to an intensifying debate over the proposed joint venture with Japan.

The FSX Debate

Opponents' View

Congressional opposition to the FSX agreement had been mounting. Yet, it was the interagency differences within the Administration that forced the postponement of the formal congressional notification. The Departments of State and Defense are staunch advocates of the program. The Commerce Department and U.S. Trade Representative officials lined up in opposition to the deal. Protests from these officials put the notification of the Congress on hold pending interagency review to resolve Administration differences.

The criticisms of the FSX program are substantial in number. Many of the opponents believe that the United States is not "getting enough out of the deal" and simply "giving our technology away."

> Critics quickly charged that Japan was getting off cheap. The deal calls for General Dynamics to get only about $440 million worth of work on the FSX, though development of the F-16 cost U.S. taxpayers $5 billion. "We're getting less than 10 cents on the dollar," says one Congressional critic.[14]

Such a technology "giveaway" is at the heart of the Commerce Department's concerns. Commerce officials fear a complete release of data to Japan ranging from the development aircraft, the YF-16, all the way through the proposed next-generation F-16, the Agile Falcon.[15] Clyde V. Prestowitz, former acting Assistant Secretary of Commerce for International Economic Policy, takes this sentiment even further:

> In addition, because GD [General Dynamics] is a competitor in the Air Force's latest development program (the advanced tactical fighter) and knowledge is fluid within the company, it is likely that some technology from the ATF program will also be transferred.[16]

In addition to the pure technical data that can be transferred, critics warn of the transfer of systems integration capability. Design and production of an advanced fighter requires advanced systems integration skills. Japanese capability has lagged behind in the integration skills considered vital for most advanced technology projects.

Opponents also are wary of the value of Japanese technology that the United States could obtain under the technology flowback provisions of the MOU. Of particular interest to the United States is the composite wing and phased array radar that Japan proposes to employ on the FSX. However, many believe the Japanese have overestimated their capabilities in these areas, and that the United States will not realize any useful technology from Japan.[17] Industry experts believe that American firms lead the world in composite technology, and that the gallium arsenide chip at the heart of the phased array radar is incapable of being produced economically at this point in time. Critics also point to the 1983 and 1985 technology transfer agreements with Japan as an avenue to purchase such technology from Japan if it does reach fruition, and at less cost in terms of our technology being "given" to Japan.

The FSX opponents quickly attack the interoperability capabilities of the aircraft. Prestowitz claims that the FSX will be stripped, redesigned and modified to the point that it will be virtually a new airplane.[18] The agreement calls for Japan to develop the radar, avionics, fire-control system and armaments. Therefore, critics claim, interoperability with U.S. forces is not a realistic goal with the FSX.

The interoperability argument will usually lead FSX opponents quickly into a critique of Japan's defense intentions. Critics contend that the FSX is a glaring example that Japan did not have defense considerations in mind when the deal was negotiated. The argument is quickly developed that if the laws of comparative advantage were followed, Japan would buy F-16s from the United States. Opponents cite the F-16 to be the premier fighter in the world, that it is available now, and that it is priced at bargain rates. For Japan to embark on developing the FSX to fill a role for which the F-16 is more than adequate is simply a waste of resources. These are the same resources which Japan could utilize to shore-up other weaknesses in its defense. Instead, this burden is shifted to the United States. Consequently, these opponents ask who is more concerned with the defense of Japan—Japan or the United States?[19]

The state of the trade deficit with Japan is also a common plank in opponents' positions. The *Journal of Commerce* addressed this argument:

> The FSX project stands in blatant contradiction to Japan's commitments to increase imports from the United States. Were its foreign trade roughly in balance, Japan's desire to build its own airplanes would be difficult to decry. But with Japan enjoying a $55 billion trade surplus with the United States last year--a surplus that is not declining--the situation is entirely different.
>
> Instead of spending an estimated $42.2 million to import each airplane from an American factory--a step which could knock $6 billion or more off Japan's trade surplus over the next decade--the Japanese government plans to keep almost all of its spending at home...[20]

Several congressional opponents are particularly upset that the Commerce Department was not consulted on the FSX. The 1989 Defense Authorization Bill contained an amendment which required that the Defense Department consult the Commerce Department before signing any MOUs. Although Commerce officials were briefed on the FSX MOU, Commerce was not intimately involved in the negotiations as some in the Congress had envisioned. In a letter sent to President Bush February 1, 1989, 12 senators expressed their concern that the long-term effects of the FSX deal on the health and competitiveness of the U. S. aerospace industry was not being considered. They cited the exclusion of the Commerce Department and the U. S. Trade Representative from the FSX negotiations as a reason for this concern.[21]

Looming over all opponents' arguments is the specter of a Japanese aerospace industry challenging that of the United States. This is a prevalent concern in the Congress, as well as in the Department of Commerce:

> [Commerce Secretary] Mossbacher's concern, shared in Congress, is that Japan will use the project as a springboard for an indigenous civilian and miliary aerospace industry that eventually would compete head-on with the U.S.[22]

This fear of competition from the Japanese industrial juggernaut extends to all sectors of the aerospace industry—military, civilian, and secondary parts. This argument is supported not only by Japanese prowess in other industries, but also by the statements of Japan itself:

> For over 30 years, Japan's Ministry of International Trade and Industry...has targeted development of a domestic aircraft industry.[23]
>
> The Japanese government has tagged aerospace as one of the country's key industries for the 1990's.[24]
>
> Though Japan's policy forbids the export of weapons, there have been calls to revise this stance. Prime Minister Noboru Takeshita has said on several occasions that Japan should have military power "commensurate" with its economic strength.[25]

Many of Japan's industrial strategies support such statements. Experts have estimated that Japan spent three times the cost to produce F-15s through coproduction rather than a straight purchase.[26] The FSX will cost much more to develop than a purchase of F-16s. Yet, "the Japanese justify that as the cost of education."[27]

Opponents warn that the Japanese policy not to export weapons is just that—a policy. One that could be reversed for economic gain.

> It would be wise for U.S. planners to further expect that not too many years down the road we could expect to see versions of Japanese combat aircraft that could be competitive on the foreign military sales market, if Japan should someday lift its ban on arms exports.[28]

If Japan holds firm on its arms export policy, opponents to the FSX still fear the aid which the program may offer to Japanese civil aviation aspirations. A 1982 GAO report on the effects which Japanese F-15 coproduction had on their civil aviation industry is a prime source for these fears. This report concluded that Japan utilizes international cooperative arrangements to further their goal of a world-class civil aerospace industry. In addition, U.S. military coproduction programs, such as the F-15, contribute to this goal by "enhancing its aircraft production and technology base with proven U. S. aircraft research and development and production know-how."[29] Supporters of this argument also quote the report's finding that a good portion of military aircraft technology is transferable to civil aircraft production. In their view, the FSX poses an even greater threat than that of the F-15 coproduction. Benefits are already being realized in Japan:

> Already, development of technology for the FSX has been used to advance such areas as metallurgical forming and bonding techniques, non-metallic materials processing and manufacturing, advanced electronics systems and optical data *transmission*.[30]

Dr. Freedenberg, in testimony to the Senate Armed Services Committee, summarized:

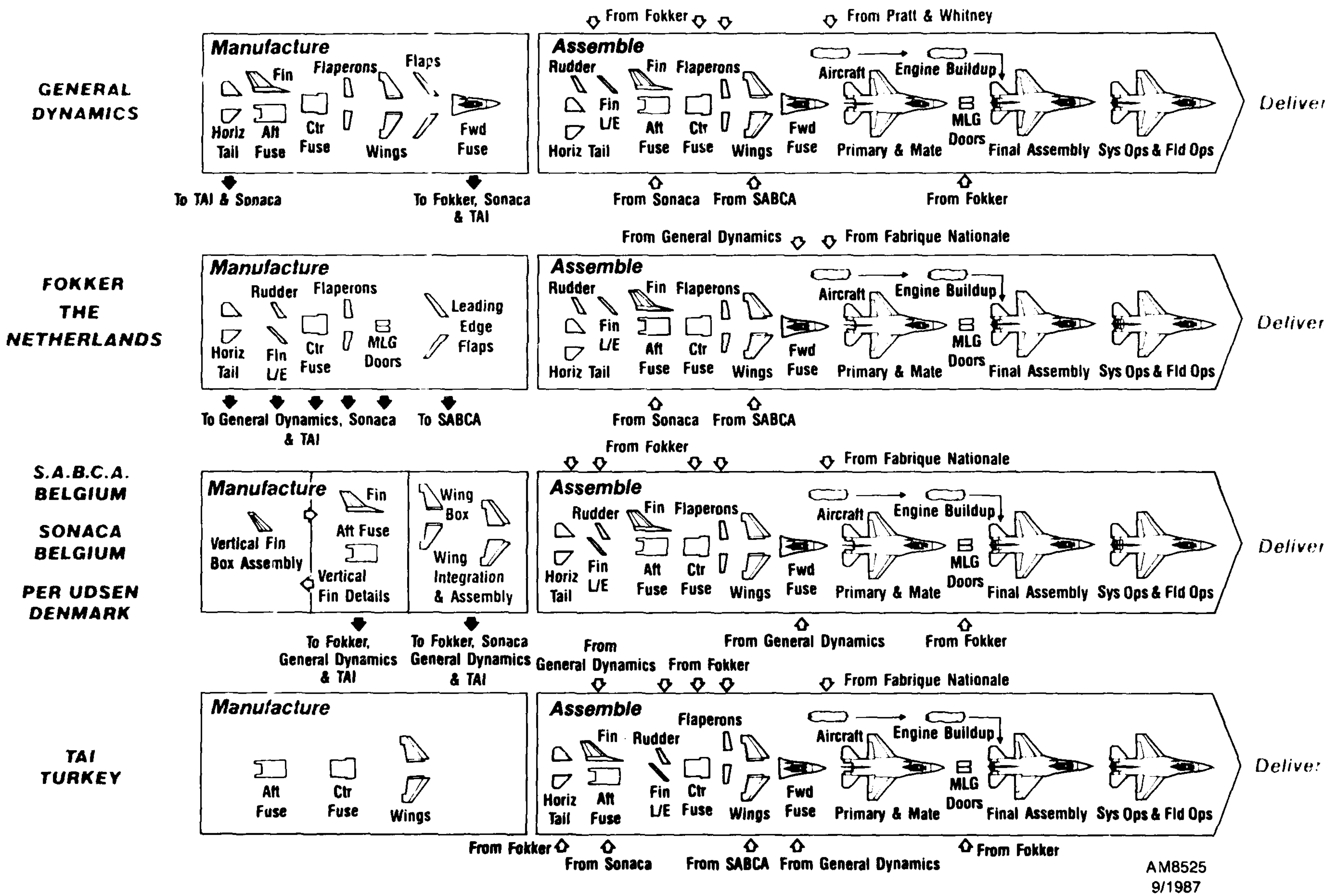
> I think from studies that have been done in the past, for example, the study of the F-15 back in 1982, it is clear that the Japanese see [the FSX] as a long-term development program for their own industry. I do not know that we have looked at it from the point of view of the long-term health of our defense industrial base to the degree that they have.[31]

Proponents' View

Such are the arguments which opponents to the FSX are offering up to the debate. *Supporters* of the agreement have fully developed their positions as well. These proponents of the FSX are quick to rebut the "technology giveaway" argument. To claim that the United States is injudiciously transferring any and all technology to the Japanese is to ignore reality, according to those involved with the program. General Dynamics cannot release any of the technical data on the FSX without approval from the U. S. Government. This approval is only granted after review by foreign disclosure personnel who are adhering to stringent U.S. technology transfer guidelines. In fact, many defense companies have complained that the process is *too* stringent.

Further, Japan would be the 15th country to participate in the F-16 program, and the 9th to actually coproduce the aircraft.[32] [Refer to Figure 1 showing F-16 components manufactured abroad]. The FSX supporters continue their case by focusing on that data which is eligible for transfer. This transferable data is much more constrained than what critics have suggested. First, only technology data applicable to the FSX configuration is subject to release.[33] Second, transfer of technology falls into the categories of engine technology, avionics, integration and airframe. The FSX engines utilized during the development of the aircraft will be *purchased* from either Pratt & Whitney or General Electric.[34] The MOU did not address the production phase of the program. Therefore, DOD has informed both Pratt & Whitney and General Electric that no arrangements for coproduction of an FSX engine can be made without the permission of the U. S. Government. Neither company is "authorized to discuss, forecast, or release data related to license production workshare, releasability, or technology transfer at this time."[35] The production FSX engine will only be discussed if and when the Japanese are prepared to negotiate the production MOU. As for the avionics, most of the systems proposed for the FSX are to be developed by the Japanese without U. S. assistance.[36] The integration technology is an area of sensitive software technology and processes. Therefore, "the U.S Government has advised Japan that certain processes associated with integration must be undertaken either entirely by Japan or entirely by the United States, and that there will be no sharing of information with respect to certain areas of integration.[37] These assertions narrow the eligible technology to that of the airframe.

FIGURE 1. UTILIZATION OF EUROPEAN PARTICIPATING INDUSTRY MANUFACTURED COMPONENTS



> Internal DoD papers explain that the airframe technology to be transferred under the FSX plan is old, "roughly equivalent to the F-15 airframe technology which Japan has had for about 10 years."[38]

Consequently, proponents of the FSX assert that the technology eligible for transfer is a rather small subset of the complete F-16 data package, and that which will be transferred is not cutting-edge technology. In reply to Clyde Prestowitz's comments, Secretary of Defense Carlucci stated:

> Mr. [Clyde] Prestowitz says that the United States has invested $5 to $7 billion in developing and refining the F-16. That number bears no relation to this project, as it includes an array of technologies that will not be transferred to Japan under this agreement. He also failed to mention that the F-16 has been coproduced to varying extents, in eight other countries since 1979, and in its present form does not represent leading-edge U.S. technology. There will be absolutely no U. S. advanced tactical fighter (so-called ATF) technology involved in building the FSX.[39]

As for the technology which is transferred to Japan, FSX proponents do not believe that it is particularly valuable to Japanese efforts other than the FSX. In fact, many believe it to be a less educational method of developing the FSX than Japanese industry pursuing indigenous development. They cite the Japanese aerospace industry lacking continuity in aerospace projects. Also, being given directions for building an airplane does not instill the knowledge that autonomous development from "scratch" would. Proponents give great credence to Japan's policy forbidding military exports. If Japan were to change this policy, officials cite several significant barriers:

1) The Japanese defense market is so small as to prevent economies of scale from being achieved at home.

2) The overall foreign military sales market in the world is shrinking.

3) Third party sales of F-16 technology is subject to U.S. approval by the MOU.[40]

The FSX supporters do not believe the program threatens the competitive posture of the U.S. civil aviation industry.

> The U.S. Air Force maintains that experience in developing a fighter is not substantially transferable to a civil aerospace industry. General Dynamics believes that under FSX, Japan is denied expertise in design technologies which are most critical for a civil aerospace industry. In addition, it is arguable that if Japan intended to develop such an industry, FSX is an inefficient approach, and investment in civilian research and development would be the more productive route.[41]

These supporters point to coproduction of the F-4, F-15, and P-3, as well as civilian licensed coproduction of the Boeing 757 and 7J7, as projects undertaken by the Japanese aerospace industry. Yet, according to these advocates, the ominous specter of a dominant Japanese civilian aircraft industry has not emerged.

Advocates of the FSX submit a lengthy list of benefits accruing from the accord. The most obvious is the financial benefit for U.S. industry. Estimates for the U.S. share of the development work range from $420 to $500 million. General Dynamics estimates that participation by U.S. industry represents 2,700 man-years of jobs that are either sustained or created during the development phase.[42] The DOD further projects that:

> The total direct and indirect economic activity created by the FS-X development in the United States, based on the current budgetary estimate, could be as high as $900 million.[43]

Although the production MOU has not been negotiated, DOD and General Dynamics have estimated the economic impact to the United States if production is undertaken and the U. S. workshare remains at the development level of 40 percent. Production could yield 58,800 man-years of jobs for the United States and generation of $2.5 to $3.2 billion of direct and indirect economic activity.[44]

Proponents also look toward the Japanese technology that the United States could gain from the program. Well-publicized technologies of interest to the United States are the co-cured wings, phased array radar, and high-speed canopy. Supporters point out, however, that there are numerous, though less publicized, technologies of equal interest to the United States (technologies that would directly advance the F-16 state-of-the-art). Critics seem relatively uninformed regarding these technologies, which include: a) advanced Japanese avionics with standardized interfaces, b) redesigned aft fuselage using Japanese composite and advanced metals technologies, c) Japanese radar absorbent material technology, and d) advancements in process technology and quality control, long recognized Japanese strengths.[45]

Proponents see a great benefit to the defense relationship between the United States and Japan. "It is in the best interests of the United States that Japan possess the best defense possible."[46] The FSX is believed to further this goal. With the third largest defense expenditures in the world and growth of these expenditures at approximately double that of NATO, the Japanese Self-Defense forces maintain a formidable presence in the Pacific:

> No one familiar with these and other realities could regard Japan as a militarily insignificant client state to which America can dictate its wishes. Japan remains a strong friend and ally that has done more in recent years to improve its own defense capability than any other U S. ally, and it continues to chart substantial progress for the future. It is within this framework that the FS-X program must be viewed.[47]
>
> [Refer to Figure 2 of Japan's contribution to defense of the Pacific region]

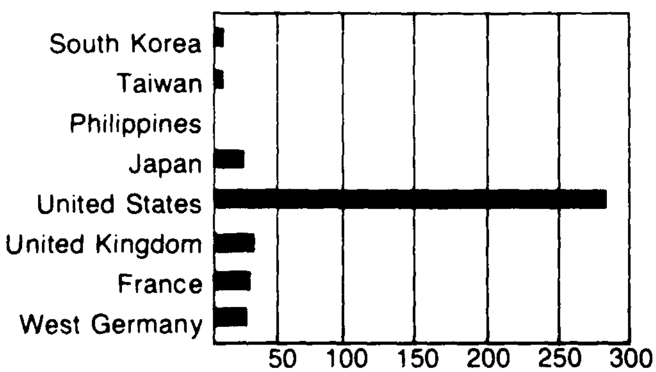
FIGURE 2. JAPAN: THE SCOPE OF THE NATION'S DEFENSE

THE FORCES

NAVY:	54 large surface warships (36 destroyers, 18 frigates), 15 submarines, eight amphibious landing ships, 84 land-based aircraft, 70 helicopters.
Personnel:	45,000
ARMY:	1,150 tanks, 385 helicopters, 590 other armored vehicles.
Personnel:	156,000
AIR FORCE:	389 combat aircraft
Personnel:	45,000

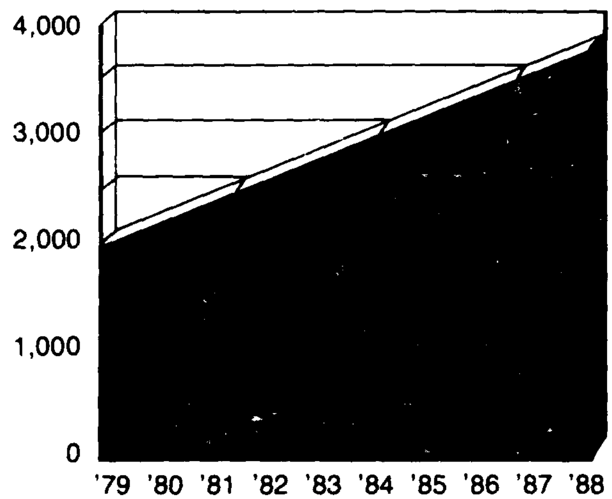
WHAT OTHERS SPEND

1987 DEFENSE EXPENDITURES IN BILLIONS OF DOLLARS



THE COST

DEFENSE BUDGET IN BILLIONS OF YEN



NOTE: Because the dollar-yen exchange rate has fluctuated wildly in recent years, figures in yen are used above. The comparable dollar values, in billions, are: 1979—$9.7; 1980—$9.9; 1981—$10.4; 1982—$11.2; 1983—$11.7; 1984—$12.3; 1985—$13.1; 1986—$19.8; 1987—$24.6; 1988—$29.7.

SOURCES: Center for Defense Information. International Institute for Strategic Studies, Jane's, Arms Control and Disarmament Agency.

Proponents also look at the future implications of the agreement. They envision joint programs between the United States and Japan that could greatly benefit both nations. Combining the skills of the two greatest economic powers on earth is an exciting prospect.

> From the U.S. point of view, shrinking domestic defense budgets mean less money for the expensive process of developing new weapon systems. And Japan could contribute by jointly developing those weapons or by providing technology to improve existing ones.[48]

Takaaki Yamada, general manager of the FSX prime contractor Mitsubishi Heavy Industries, views the agreement in terms of future cooperation, not competition:

> "We are not talking about sending small planes to America the way Japanese industry sent small cars," he says. Instead, the skills MHI picks up will be "very useful for Japan-U.S. *joint* development of aircraft and for civil aircraft ventures, too."[49]

However, proponents fear that if the United States reneges on the FSX deal, that future agreements would be difficult to pursue.

Advocates of the FSX strongly urge critics to focus on the realities surrounding the deal. They will be the first to state that a straight purchase of F-16s by Japan would have been preferable. However, this avenue was never a real possibility. The alternative to the FSX deal was indigenous development of the fighter by Japan. These proponents will argue that it is reasonable for Japan to have wanted to pursue domestic development.

> The Swedes are building their own plane, so are the French, the Indians and others. Don't we expect the Japanese to want to do the same?[50]

In addition, advocates insist that the agreement must be looked at in the context of the realities of the international defense market:

> ...any restriction on the availability of prime contractors to use offsets and coproduction [for the FSX] will be absolutely useless. The Japanese already have a manufacturing capability in many subsystems which has developed as a consequence of earlier aircraft programs, and it is conceivable that, given a national dedication to a design effort, they could design their own aircraft. Perhaps more likely, if U.S. suppliers were out of the picture, there are a number of other countries and companies which would be glad to fill the vacuum.[51]

Consequently, proponents of the FSX believe the United States negotiated hard and received a favorable deal. The Senate Armed Services Committee stated in April 1988 that it "regarded codevelopment and coproduction [of the FSX] as the next best alternative" to a straight sale of F-16s. This same committee stated that U.S. negotiators should ensure that the United States receive a favorable workshare in the agreement, and that Japanese technology developed under the FSX "flows back expeditiously and without charge."[52] Proponents believe negotiators of the agreement fulfilled these requirements and provided the United States a fair and beneficial agreement with Japan.

Resolution

The FSX agreement was negotiated by the Reagan Administration, but President Bush's Cabinet was tasked with implementing the accord. Concurrent with the change in Administrations was the raising of voices in the debate over the FSX:

> Problems occurred only when the new U.S. Administration came in. Objections were raised by the Secretary of Commerce (Robert Mossbacher), the special trade representative (Carla Hills), as well as those on the far right in Congress (Jesse Helms) and the Democratic left (choose one of several). The pot was artfully stirred by some with knowledge of Japan (including Clyde Prestowitz, a former U.S. government official) and warmed up by some prominent U.S. publications.[53]

Not only were new voices in the debate being heard from the recently formed Bush Cabinet, but the debate was refueled by a growing interest in Japan. The death of Emperor Hirohito, the burgeoning trade deficit, and the political scandal within Japanese Prime Minister Takeshita's cabinet drew attention to our Pacific Ally.

President Bush found himself sorting out the arguments offered for and against the agreement. The Pentagon and National Security staff supported the FSX, while the economic agencies of the government lined-up in opposition.[54] Leading the opposition within the Cabinet was Secretary of Commerce Robert Mossbacher, who advocated a greater role for his department in the FSX and future MOUs. Secretary Mossbacher proposed that "As we lessen the apparent risk of actual warfare...we find that we are moving from battleships to the trade aspects of our international relationships. U.S. policy has changed."[55] Several news accounts characterized these views on the FSX as a "donnybrook" between the Pentagon and the Commerce Department. In this battle within the FSX war, Mossbacher claimed a victory. Not only did the Defense Department agree to share power with the Commerce Department in approving future weapon deals, but Commerce also won a role in monitoring the technology flows under the FSX.[56] However, this agreement occurred without the President's decision on the FSX program.

The Cabinet took the issue directly to President Bush at a March 14, 1989, meeting of the National Security Council. From this debate before the President, three major issues were offered for the President's consideration:

1) Inclusion of source codes in the FSX agreement. Such source codes are likened to blueprints for software. Concern centered upon source codes for fire control and flight control systems.

FIGURE 3. KEY POINTS IN THE FS-X DEBATE

PROPONENTS	OPPONENTS
1. Technology Not New; F-16 Already Coproduced; Strict Tech Transfer Guidelines	1. Technology "Give-away"
2. Technology Not Transferrable to Civil Aero Industry	2. Technology Flowing Back to U. S. Overestimated
3. U. S. Industry Benefits: Financial, Jobs	3. Interoperability Unlikely
4. Access to Japanese Process Technology & Quality Control	4. U. S. Trade Deficit Further Aggravated
5. Strengthened U. S.-Japanese Defense Relationship/Future Joint Programs	5. Commerce Dept not Consulted, Industrial Base not Protected
6. Realities of Int'l Defense Market Dictate "Cooperation"	6. U. S. Creating a Direct Aerospace Competitor

2) Clarification of technology that the United States would receive from Japan.

3) A guarantee of U.S. share in the *production* phase of the aircraft.[57]

President Bush decided to go forward with the FSX, contingent upon "clarification" of these issues with Japan.[58] What followed was a reopening of discussions with Japan on the FSX agreement. Japan sent a delegation to Washington on March 22, 1989, to dissuade the President from changing the agreement. Kichiro Tazawa, Director General of the Defense Agency, called on the United States to "respect what has been agreed to in the memorandum of understanding."[59] However, Washington stood its ground on areas of protecting U.S. technology, delineating what Japanese technology would be transferred to the United States, and demanding a 40 percent U.S. workshare in any subsequent production.[60] As discussions with Japan continued, Japanese sources were quoted regarding displeasure with Washington's reopening of a "done deal." Japanese officials were quoted as saying such discussions would "leave a very serious scar in the minds of people who should be cooperating with each other." The Japanese delegation left Washington on March 29, 1989, without an agreement. However, Japan did award an $81 million contract to Mitsubishi Heavy Industries on March 30, 1989, for the FSX development.[62]

As discussions between the United States and Japan continued, developments added high drama. Japan was forced to negotiate from a position in which Prime Minister Takeshita had announced his resignation due to the recruiting scandal his government had incurred. Some accused Mitsubishi of being involved with the sale of chemical warfare equipment to Libya. Such factors figured with the already-present trade friction to demand that both sides reach a politically palatable agreement. The media reported rumors that the Japanese had reopened discussions with France and Israel to explore replacing the United States in the FSX deal.[63] The United Auto Workers and International Association of Machinists and Aerospace Workers demanded the agreement be scrapped.[64]

The United States and Japan finally reached an agreement on the FSX. On April 28, 1989, President Bush announced that the two governments were able to reach an agreement "that will allow us to proceed with joint development of the FSX fighter aircraft."[65] The new agreement included:

1. A 40 percent U.S. workshare in both the development and production phases.

2. Control of the F-16 source codes to allow access to only those necessary to complete the project.[66]

The Administration performed required notification of the Congress on May 1, 1989, and the Congress had 30 days to review the agreement. Resolutions in the Senate and the House were introduced to block the FSX.[67] Opponents would have to muster a two-thirds vote to override a Presidential veto of any such resolution. This is not seen as likely to occur, even among the opponents themselves.[68] Consequently, though critics of the FSX will wage their battles in the Congress, it appears the FSX has weathered the storms of controversy and will aim toward a maiden flight in 1994.

Summary

It seems apparent after reviewing arguments for and against the FSX that the debate has no clear victor. (See Figure 3 for a summary of key arguments.) Though difficult, careful weighing of benefits versus drawbacks is necessary. The debate over the FSX agreement thereby implies more than just the fate of 130 aircraft for the Japanese Air Self-Defense Forces. Instead, it ushers in a new era of relations and agreements with Japan. The challenge is to change our national image of Japan as a delicate ward of our nation to a view of Japan as our economic equal. In today's increasingly interdependent world, this challenge may extend beyond Japan. Today's world demands a new perspective on behalf of the United States. Requirements for the 1990s will be international cooperation, while always attempting to protect U.S. interests to the greatest extent possible.

Whether or not the FSX comes to fruition, the program highlights significant trade-offs, benefits versus drawbacks, that must be weighed by any country considering an international cooperative program. Equally important, the FSX debate highlights the need for a coherent process to evaluate the political, economic, military, and technological advisability of any potential international project.

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The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of Defense or the U. S. Government.

Editor's Note: In a much closer vote than expected, the Senate failed to block the FSX program (the resolution for disapproval of the program was defeated in a 52-47 vote). Subsequently, however, twin resolutions were introduced in both the House and the Senate to impose new conditions on the implemention of the program. Fearing untenable restrictions and the prospect of reopening negotiations, the White House is expected to veto any such legislation.

ETHICS IN GOVERNMENT CONFERENCE

The American Society for Public Administration is sponsoring a national working conference and dialogue on applied ethics in government Nov. 12-15, 1989, at the Hyatt Regency Washington. It will bring together executive, legislative, and judicial officials from federal, state, and local governments, major thinkers and writers on the subject, and other interested people.

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Ideas and suggestions regarding program design and content from interested individuals and organizations are welcome. Please send them to: Ethics in Government Conference, American Society for Public Administration, 1120 G Street, NW, Suite 500, Washington, DC 20005, (202) 393-7878/FAX (202) 638-4952.

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SYSTEM DYNAMICS AND STRUCTURED IN POLICY ANALYSIS

Rolf Clark

This is an overview of System Dynamics, a new and useful analytic tool for policy analysis.

Policy problems concern important questions of a broad nature about the long-term. Management problems tend to be of narrower scope and shorter duration. For example, decisions on what fraction of excess financial resources to invest in stocks, as opposed to bonds, are policy related. Once an investment policy has been made, it is management's problem to determine exactly which stocks to buy, when to buy and sell each, how to pay for and account for them, where to retain the stock certificates, and so on. System Dynamics is not a method for detailed management of resources. It is a method for systematically considering policy options.

Evolution of Realism in Policy Analysis

If a policy problem is too complex to treat analytically, we often simplify the problem assumptions until the analysis becomes mathematically tractable, sacrificing realism for the sake of solution. We often apply "linear thinking" to dynamic processes. Today's newspaper says the trade deficit is decreasing. Using linear thinking, it will surely eventually become negligible or zero. The decrease may feed back as diminished concern about trade deficits, which will lead to policies increasing the deficit, and at accelerated rates.

Such oversimplification leads to loss of validity, as assumptions in the analysis become unrealistic, or implicit, or unknown, or even erroneous, just as assuming that decreasing deficits mean that deficits will continue to decrease.

We might conclude that policy problems are complex, too complex for comprehensive analysis. Yet, the modern microcomputer and, specifically, computer simulation has been used in problems as complex as sending man to the moon. Simulation has made excessive problem simplification unnecessary. Yet, oversimplification in policy analysis persists. Why?

The way analytic methods evolved is one reason. Virtually all popular analytic techniques were developed in academic settings—universities, laboratories, think tanks. Students learned the techniques from faculty who learned the same methods a generation or two earlier. The university tenure system essentially assures a slow turnover in teaching faculty, so most methods taught during 1950-70 were developed before the advent of computers and convenient software. Before computing advances of the 1970s, analytic solutions were essential and mathematical tractability was a necessary core for most analytic methods. Mathematical programming, statistics, econometrics, input-output analysis, queueing theory, decision analysis, and network theory are examples of "static" analysis techniques still dominating departments of operations research, management science, and policy analysis. The steady-state nature of these methods virtually precludes the transient state (or "dynamic") analysis needed for understanding complex social policy problems.

True, engineering schools did develop dynamic methods, particularly in the area of control theory. But differential equations, which comprise the mathematics of control theory, are limited to solutions of third or, at best, fourth order differentials. Policy problems usually require 20th or higher order differential equations, replete with complex feedback relationships. Besides, policy analysis was not of high interest to the engineering disciplines.

With the advent of high-speed computing capabilities, analytic solutions could be abandoned and replaced by simulations that replicated the richness of a policy problem. Many variables could be interrelated in a model of the system being studied with lags, feedbacks, biases, and even perception errors included; alternative policies could be explored through high-speed iterations of the computer model.

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Today, dynamic simulation, a mathematically unsophisticated method, is of little appeal to academics, and is rarely taught in schools of business, social studies, or engineering. However, MIT's Sloan School has produced the small swell of activity in a powerful method of policy analysis called "system dynamics," a simulation based on the theory of stocks and flows.[1]

What is needed for advances in policy analysis are simulation efforts of a moderate scale, worked on by combined talents of managers, quantitative analysts, and computer experts focused on specific policy issues. In defense acquisition, for example, simulations could be useful in studying the complexities of instability in planning and funding, in life-cycle costing, in hardware/manpower tradeoffs, in the economic impacts of various policies on the industrial base, in disarmament, in strategic defense initiatives, and so forth.

What is needed for advances in policy analysis are simulation efforts of a moderate scale, worked on by combined talents of managers, quantitative analysts, and computer experts focused on specific policy issues.

In this article, I introduce system dynamics as a discipline for structuring the analytic thought process to study any system. It will be shown as an excellent tool for communicating understanding of a system between interested parties. We will be interested particularly in managerial systems such as those found in finance, logistics, acquisition and cost estimating but the discussion could as well be concerned with the environment, populations, prey-predator situations, epidemic growth, or international trade.

Systems—What Are They?

To understand a policy problem—to conduct policy analysis—we must understand the system affected by the policy in question. What, then, is a system?

Systems surround us. Crime in the streets, a clock's pendulum, a runner's physiology and the acquisition process are systems. What defines a system? A typical definition is "a grouping of objects that operate together for a purpose."[2] That definition, however, also describes a pair of pliers. We need more insightful descriptions.

Interesting systems have three basic qualities. First, they are made up of structural components like the pipes and tanks in a refinery system. Second, material flows and accumulates within the structure like petroleum in the pipes and tanks at the refinery. Third, these flows and accumulations occur over time, making them dynamic.

Some system components (the "controls"), control the material flowing through the structure.

The material in a system is either accumulating somewhere, or it is flowing between accumulations. The accummulations are called "stocks," and the flows are simply called "flows." The material movements in every system can be specified in terms of stocks and flows. In the refinery, tanks contain stocks of material that have accumulated, and pipes (with valves as controls) direct flows of material between stocks. Stocks are usually measured as absolute quantities like gallons or tons, or dollars. Flows are measured as rates of change, specifically the change per unit time of the stocks. Gallons per hour, tons per year, or dollars per week are examples of material stocks and flows.

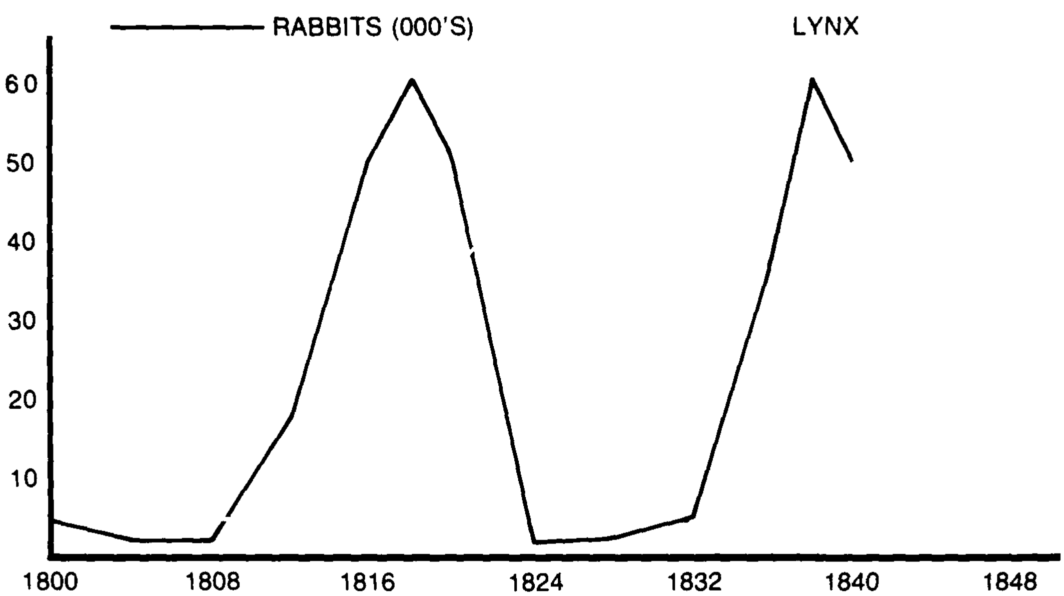
Systems surround us. Crime in the streets, a clock's pendulum, a runner's physiology and the acquisition process are systems.

The material need not always be something tangible like oil or dollars or people. Sometimes, the material accumulations are more abstract. Prices, or temperature, or attitudes can be stocks, in which case the "flows" are price change, temperature change, and attitude change.

Stocks and flows form the basis for structuring the analytic thought process about systems. The stock-flow logic makes it easy to model systems, and to make the systems understandable.

The material stocks and flows comprise conservative parts of the system. An element of material can only be in one place at a time. Either it is held in a stock, or it is flowing between stocks. Since material cannot be in two places at once, it is said to be "conserved." Information about the material, on the other hand, can be used in numerous places at once. The amount of material in an inventory, for example, can be provided as information to accounting, to receiving, to shipping and to management, simultaneously. All rates of material flow in a system are dependent on information about other parts of the system. Flow valves are opened

FIGURE 1. RABBIT-LYNX CYCLE



or closed depending on levels of stocks in various parts of the system. For example, the rate of change of price level may depend on information about inventory levels, past orders, and average recent sales. Such "information flows," more properly called information "links," are not conservative, which means the same information can be used in several places at once.

A stock is only dependent on the material flow directly entering or leaving that stock. For example, a stock of inventory is increased by orders received and decreased by sales. Flows, on the other hand, can be dependent on any of the system's stocks, not just stocks directly affected by the flow pipeline. This dependency is defined through the information links to system stocks.

Thus, the flow of orders (to replenish inventory) may depend on information about the current stock of inventory, the level of desired inventory, the backlog of orders already sent and, perhaps, the average delay in receiving goods.

At any point in time, each stock has a numerical value, called its "level." If a tank contains 10 gallons, its level is 10.0 gallons. Each flow also has a value, called its "rate." Oil flowing out of a tank at 3 gallons per minute, has a rate of flow of 3.0 gallons per minute.

Exactly how one models a system—that is how one determines the appropriate stocks and flows of material—and how one defines information links defining flows quantitatively, requires modeling experience. It is the task of the technician, the modeler, to work with the policy analyst to help build a policy model. And the policy-maker must communicate with the analyst regarding the needed policy explorations. I cannot, here, discuss complete details of necessary modeling skills. We can only provide an overview of how system dynamics works. Two examples follow.

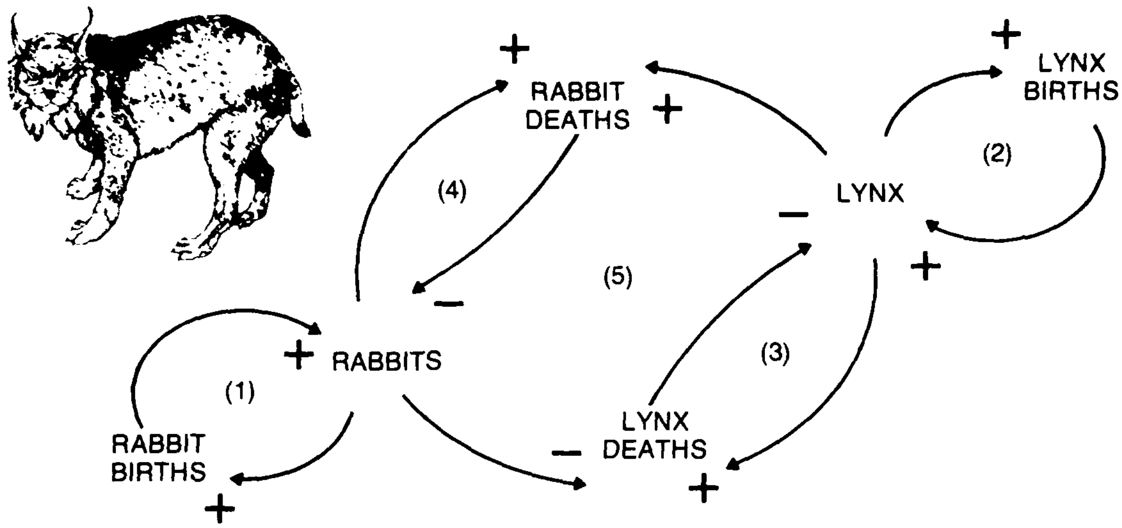
A Prey-Predator Model: Lynx and Rabbits

Figure 1 is derived from data on the ecological system near the Hudson Bay in the early 18th century. The populations of lynx, and of rabbits, show dramatic oscillations over time. As rabbits provide a major food source for lynx, the populations are clearly interdependent. We can demonstrate the system dynamics method by building a model which produces population swings as those shown. A modification of the same model could be used for any prey-predator situation, such as submarines versus destroyers, or tribal warfare.

The relationships between populations of lynx and rabbits are clearly dynamic. There seems no steady state, and static methods for understanding the relationship between the prey and the predators would fail to be comprehensive. The cyclical nature of the populations and their interrelationship could, in this simple case, be mathematically defined in terms of differential equations. But, instead, we model this system to demonstrate the method.

The first step is to acknowledge there are various feedbacks operative in this simple system. Feedback means that one problem variable cannot be calculated without knowing a second variable's value, and yet the second variable is dependent on the value of the first. Avoiding simultaneous feedback (so the problem can be solved) then requires relating the two variables by considering their relative "rates of change" over time, as well as their absolute values.

FIGURE 2. FEEDBACK RELATIONSHIPS



This sounds complicated. . . and is. The process requires differential calculus to "solve" the problem, but if the analyst is satisfied with "exploration ("what-if" analysis), then simulation comes to the rescue. Figure 2 provides feedback relationships in this problem.

Arrows show the direction of impact of one variable on another, and the "+" and "—" signs at the tips of the arrows indicate whether an increase in one factor causes an increase (+) or a decrease (—) in the second. More rabbits, for example, mean less lynx deaths (through adequate food supplies for lynx).

There are five basic feedback loops in this problem. Loops (1) and (2) represent positive feedbacks. Increased births mean more population and more population means more births. Loops (3) and (4) are negative feedbacks. More deaths mean less population but less population means less deaths. Loop (5), a more complex negative feedback loop, captures the interaction between rabbits and lynx. Growth in the lynx population means more rabbit deaths (through kills), which means less rabbits. But, less rabbits means increased lynx deaths (through starvation), feeding back to offset the growth in the lynx population.

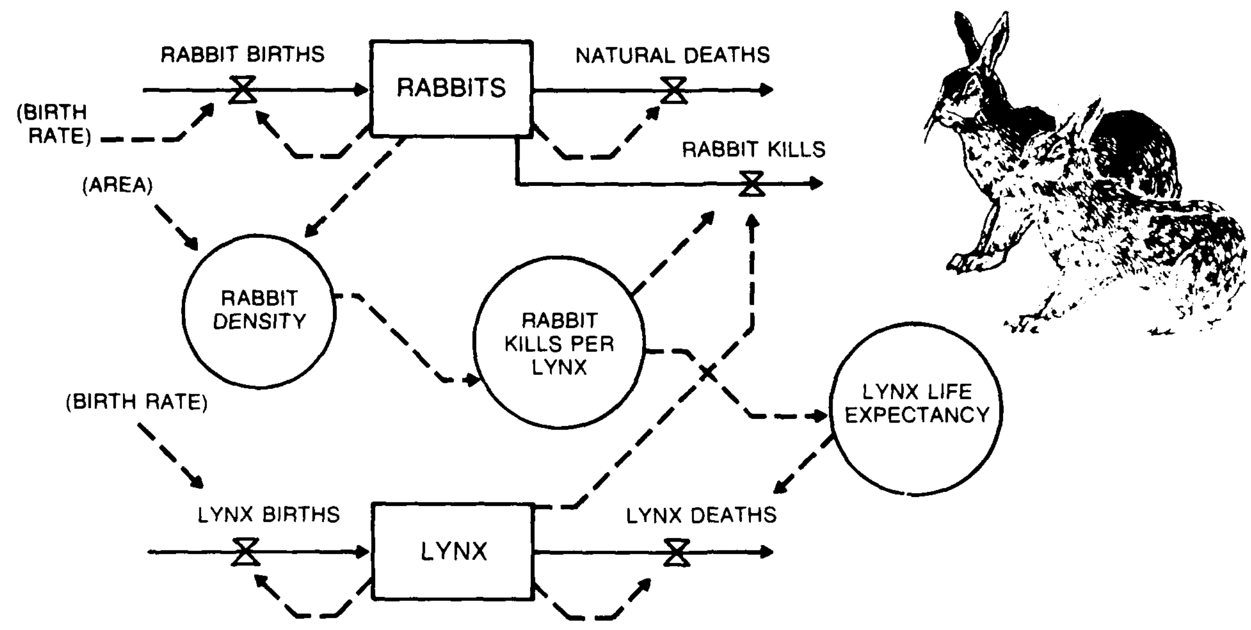
What is important is that there are five feedback loops operating simultaneously and the analysis, even in this simple system, requires accounting for all these dynamic relationships at once. The question is how this can be done analytically.

> In effect, a system to be simulated is defined through a set of simple equations that are calculated in turn, instead of one complex (differential) equation that relates all variables at once.

System dynamics simulates the system by sorting all the variables into stocks and flows, and then finding relationships between them. Figure 3 shows the conversion of the causal relationships in Figure 2 into a stock flow-diagram. The symbology is common to system dynamics modeling. Stocks are shown as rectangles, and flows as the butterfly-shaped symbols representing valves which control the material flow. The variables in large circles are auxiliary relationships that help define the rates of flow by disaggregating complex expressions into a series of simple expressions. The solid arrows, which always pass through a valve, represent the conservative flows—material passes along these "pipelines" through a flow valve. The dotted-line arrows represent information flows.

In the diagram, the rabbit kills (a flow) can be derived from information about the lynx population (a stock) and the number of rabbits killed per lynx (an auxiliary). Rabbits killed per lynx depend on the rabbit density, which is simply rabbits divided by the land area.

FIGURE 3. LYNX-RABBIT STOCKS AND FLOW MODEL



Each variable in Figure 3—there is one variable for each symbol—can be defined only by the variables that affect it. The stocks are affected only by the flows into and out of them, and the rates and auxiliaries are affected by the variables linked to them through information flows. **This means the system can be modeled by writing simple equations for each variable, rather than trying to relate all the variables simultaneously.** This is the essence of simulation.

In effect, a system to be simulated is defined through a set of simple equations that are calculated in turn, instead of one complex (differential) equation that relates all variables at once. The series of calculations are performed at one point in time, and then recalculated each time-step thereafter until the time horizon of interest is completed. In other words, the system is "simulated" over time.

We are not interested, here, in modeling details. The exact form of the equations are of no value for now. It is important to know, however, that the stock-flow modeling methods exist, and are well supported by software geared to allow "what-if" explorations of how the system operates over time. Policy analysts, with the assistance of analysts versed in the method and the software, will be able to explore rather complex dynamic systems without needing to make unrealistic assumptions or qualifications, such as requiring steady state for their analysis to be valid.

Rather than pursue this problem further, we can turn to another example to broaden the discussion. Should the equations for Figure 3 be developed and simulated, then the rabbit and lynx dynamics similar to those in Figure 1 would presumably result, and analyses could be conducted to see the impact of different policies. One might explore the effects of bounties, say, on either rabbits or lynx, as a way to stabilize the extreme population swings.

Instead of modeling a simple prey-predator situation, one can apply the same methods to, say, the financial dynamics of a corporation—or of the national economy.[3] The economy is made up of stocks and flows, just as is the lynx-rabbit.

Readers interested in a more complex example may benefit from the following example.

A Financial Analysis Model

This example applies system thinking to the financial dynamics of a firm. Specifically, by using the firm's balance sheet, income, and fund flow statements—and reasonable assumptions about the firm's policies on control of inventory, debt, and physical assets—a projection of the firm's future will evolve. The example is kept simple to avoid obscuring tutorial aspects,[4] yet is reasonably comprehensive in its use of system dynamics. As most readers will have had some exposure to financial statements in their usual static form, an expansion that incorporates dynamic possibilities can provide useful insights.

FIGURE 4. FINANCIAL INFORMATION, XYZ CORPORATION

BALANCE SHEET (000's)

ASSETS	1981	1982	EQUITIES	1981	1982
Current					
Cash	600	785	Debt	14,123	15,177
Inventory	12,000	12,624			
	----------	----------			
	12,600	13,409			
Fixed Assets			Owner's Equity	3,477	3,646
Plant & Equity	10,000	10,490			
Accumulated Depreciation	(5,000)	(5,076)			
	----------	----------		----------	----------
Total:	17,600	18,823		17,600	18,823

Income Statement For Year Ended 1982 (000's)

Sales:		56,784
Less: Cost of Goods Sold	50,610	
Gross Profit:		6,174
Less:		
G&A Expenses	4,172	
Depreciation	376	
Earnings Before Interest & Taxes		1,626
Less: Interest Expense	854	
Earnings Before Taxes		772
Less: Taxes		371

Net Income:		401

Sources And Uses Of Funds, 1981-82

Sources		Uses	
From Operations		New Plant & Equipment	866
Net Income	401		
Depreciation	376		
Increased Debt	1,054		
	----------		----------
	1,831		866

Note: Disposal of Plant and Equipment (zero salvage value) = 300

Figure 4 provides a balance sheet and relevant funds flows for a hypothetical firm.

The task is to use these financial data to develop the firm's likely financial future. This requires being able to project future balance sheets, income statements, and associated financial measures derived from them. We will concentrate on projecting two measures: the debt/equity ratio and the profit margin, both of which require future balance sheet and income statement variables.

The Stock-Flow Logic

Thinking dynamically about this firm, one begins by choosing likely stocks in the stock-flow logic. Stocks are accumulations, and the balance-sheet items clearly represent accumulations. Debt is accumulated borrowing, inventories are the net accumulation of purchases less sales, plant and equipment is the accumulation of new investments less disposals. Cash on hand represents the accumulation of net cash flows.

Flows, on the other hand, are the changes to stocks per unit of time; represented by the income and fund flow statement items. In this example, the fund flows are changes to the balance sheet items from year to year. Figure 5 provides a stock flow diagram to help the discussion. Remember that the rectangles represent stocks, and the valve symbols represent flows. The double valve symbol shown for "new debt" indicates that any new borrowing increases debt, and also exactly equals the addition to cash that the borrowing provides.

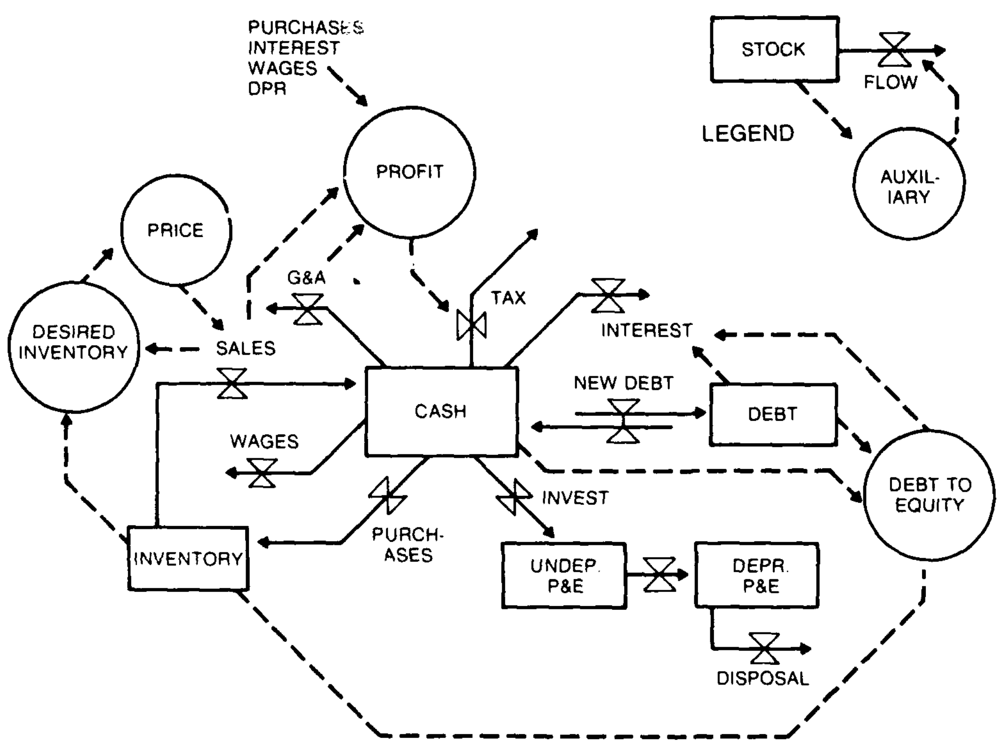
Let's explore the stock-flow versus balance sheet-income statement logic in more detail.

"Cash" is a stock that at any point in time has accumulated all cash flows. Its central location in the diagram shows the cash account as the clearing house for two types of transactions: first, those that change the levels of debt, inventory, and plant and equipment (P&E); and, second, those expenses like general and administrative (G&A), wages, interest payments and taxes. The latter are shown in Figure 5 as not flowing to any asset or liability account (the stocks), but rather to the environment outside the system being modeled.

Plant and equipment is an accumulation of investments less disposals. It is a stock. However, to be consistent with the accounting practice of accumulating depreciated P&E that is not yet scrapped or sold, it becomes necessary to break P&E into "underpreciated P&E" and "depreciated P&E." The flow of funds is a conservative flow—money cannot be in two places at once. This requires mutually exclusive categories for depreciated and undepreciated P&E, instead of the categorization used on the balance sheet.

The flows in Figure 5 have already been partly defined. "Investment in new P&E" increases undepreciated P&E while "depreciation" reduces this stock over time. In turn, "depreciation" increases depreciated P&E while "disposal" reduces it. "New debt" flows into debt. Cash is increased by the

FIGURE 5. FINANCIAL STOCK/FLOW MODEL



flows of "new debt" and "sales," and decreased by the cost of goods sold, approximated by the flows "wages" and "purchases." Cash is also decreased by "general and administrative" expenses, "interest" paid on debt, "investment" in plant and equipment, and "taxes."

Various auxiliary variables are used to derive factors that affect the numerous flows and reflect policies used by the firm. Sales, for example, are affected by prices, and pricing depends on demand. The relationship between price and demand must be obtained from outside the model, through statistical data on past price/sales information perhaps. Then, a pricing policy is determined, with price changes dependent on management's view of the firm's position. Probably, prices will depend on the ratio of actual inventory to a desired inventory level. If inventory is too high, price is reduced. Desired inventory will, in turn, depend on past sales. Thus, the feedback nature of business becomes clear.

The financing of funds needed for investment depends on the policy concerning debt/equity ratios. This will determine whether new investment is funded out of retained earnings (that is, cash), or out of new debt. Purchases of raw material (part of the cost of goods sold) will depend on actual inventory as compared to desired inventory, which again may depend on average past sales.

Determining Equations For Flow Variables

In order to obtain future values of the numerous financial variables for this firm, equations for each flow variable must be derived.

Determining the flow equations requires specifying the relationships between balance sheet and income statement variables. The actual fund flows provided for the year shown, in concert with the balance sheet items, can be used to impute the relationships from the data. For example, as depreciation for 1981 was $376 and undepreciated P&E was $5000, one reasonable assumption is that annual depreciation is about 376/5000 times undepreciated P&E. In Figure 5, this means the equation for depreciations is:

DEPR = .0752*(UNDEP P&E).

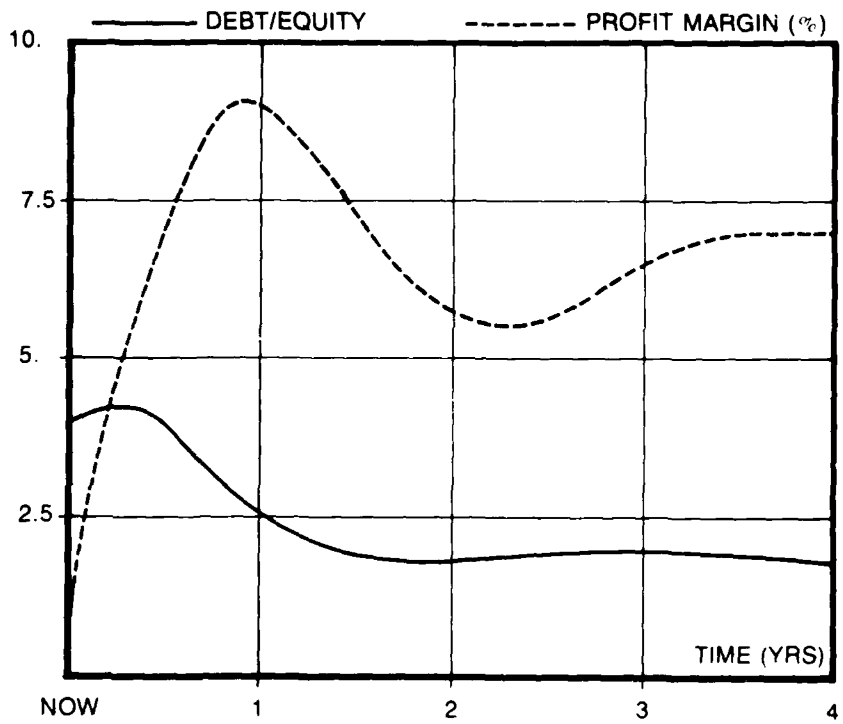
Many of the model relationships would require knowing such policies. The modeler would obtain these from the firm's executives. Here we must continue to select a few arbitrary policies.

The firm's pricing policy may depend on inventory levels. Let us assume that price is lowered proportionate to the fraction that inventory exceeds desired inventory. If inventory is 10 percent too high, price is lowered 10 percent. But, what is "desired" inventory? Desired inventory may depend on past sales: the firm's inventory policy may be that desired inventory is a fixed fraction of average sales over the past few months. Sales, of course, respond to price levels, and statistical data would be needed to obtain product demand as a function of price. The feedback nature of business again emerges.

Another policy would involve investment funding. How much of the demand for new plant and equipment should be funded out of cash on hand, and how much out of new borrowing? How should investment in new plant and equipment be estimated? Perhaps desired P&E has some relationship to sales and to projected sales, each of which can be obtained from past data, and new borrowing will only occur if cash on hand is below some desired level, which also depends on recent sales activities.

While the process is more complex in reality, such policy modeling can be accomplished fairly realistically—so long as the modelers work with the firm's executives, and vice versa. This policy determination process, along with the stock-flow system mechanics, brings financial analysis from a static

FIGURE 6. SELECTED FINANCIAL MEASURES



"balance sheet/income statement" logic, to a dynamic form of financial analysis. Policy analysis, at least the capability to conduct "what-if's," falls out rather naturally.

Let us demonstrate. Various financial measures, such as the debt-to-equity and profit-to-sales ratios shown in Figure 6, are easily defined using normal financial values, and show the firm's likely future during the next 4 years, if it continues present policies.

Profit margins change over time, and are of obvious interest to management and owners. Decreasing profits should be viewed relative to the financial dynamics over time, rather than as pure indicators of relative failure. Figure 6 shows profit dynamics that naturally occur from constant policies followed by this firm.

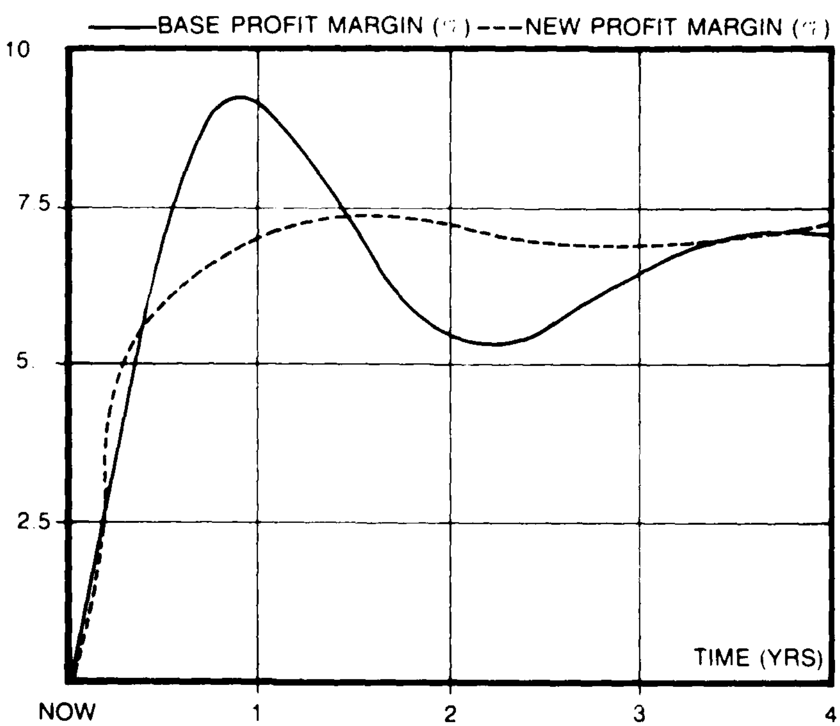
Interest payments will, in a realistic situation, be dependent on debt to equity ratios, which depend on financing policies. Excessive debt will cause interest rates for new debt to rise. Figure 6 demonstrates debt/equity ratios for our hypothetical firm.

The cyclical nature of the changes in the variables shown results from the numerous feedbacks between variables. Even in this simple example, inventory affects price, which affects sales, which affects investment in P&E, which affects production, which feed back to affect inventory.

With feedback like this, it would be unrealistic to model the financial future of a firm by using static methods. Much of a firm's behavior over time is caused by internal reactions to internal policies. Static methods, on the other hand, require assuming that behavior responds to external factors.

Once a model is built and debugged, alternative policies—on pricing, on inventory control, on investment decisions—can be explored by running the model with each policy result compared against the current policy.

FIGURE 7. SELECTED FINANCIAL MEASURE WITH NEW PRICING POLICY



Pricing policy is a major profit driver in this firm. Figure 6 resulted from a pricing policy that called for a proportional reduction in price when inventories were too high. Specifically, if inventories were, say, 20 percent higher than desired, price was lowered half as much, or 10 percent, and vice versa if inventories were too low. This pricing policy can be tested for improvement. Figure 7 shows profit stability resulting from a new, less reactive pricing policy in which prices are reduced only a fourth as much as the desired inventory correction, instead of half as much as was true in the base case.

If profit stability is a concern of the firm's owners, the new policy may be preferable. Overall profitability over the 4-year horizon is approximately the same for the two policies, as the area under the two curves is approximately equal.

Similar policy analyses might be run to determine potential improvements in borrowing policies, in investment policies, and in inventory control.

The system dynamics software allows rapid sensitivity analyses of policy options—"what-ifs" are easy.[5] The software also provides automatic model documentation, flexible report generation, and executive interface routines so that models can be called and exercised through menus by someone not familiar with the model itself, but eager to exercise it in a policy mode

Conclusion

Complex systems can be efficiently modeled using system dynamics. Output from such models provide visual results understandable and useful to policy-makers.

It is important to understand that the method is a policy method, and not a management tool. This means that system dynamics helps in exploring policies about logistics, but will not keep track of each individual part in a logistic system. It also can be used to explore the large-scale implications of an early release manpower policy, but cannot keep track of each person in the manpower pool. Force level losses associated with instability in the 5-year plan can be explored but each individual program and its changes within the plan cannot be tracked.

Realistic policy analyses can be conducted on systems in their transient states, using mathematically simple simulation methods augmented by graphical output. System dynamics provides well established tools to conduct meaningful dynamic analyses.

The Defense Systems Management College has expertise in this area, and is available for consultation in the value of using the method for policy analysis needs. Contact the Research Directorate at DSMC.

Endnotes

1. The originator of System Dynamics is MIT's Jay W. Forrester, an electrical engineer, whose original work evolved into *Industrial Dynamics*, MIT Press, 1961.

2. Forrester, *Principles of Systems*, Wright-Allen Press, 1968 (Page 1-1).

3. As is being done currently at MIT. For a description, see Clark, R. H., "A Dire Economic Future? MIT's National Model Projections," *Program Manager*, November December 1988.

4. For a rather thorough effort to study financial dynamics of a firm, see *Corporate Planning and Policy Design: A System Dynamics Approach*, James M. Lyneis, MIT Press, 1980.

5. Several software packages are available. DYNAMO (Pugh-Roberts Associates, Cambridge, Mass.) and DYSMAP (University of Bradford, England) are available for the IBM PC clones; STELLA (High Performance Systems, Lyme, N.H.) is popular for the MacIntosh.

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14 March 1989

Editor:

I recently read an article in the November-December 1988 *Program Manager*, entitled, "Manpower Estimate Reports: Implications and Relationships," by Dr. Robert Boynton. This is a very informative article and the manpower concerns it raises with developing and fielding our new weapon systems are valid.

In this article, Dr. Boynton references the Small ICBM (Midgetman) program in the following context: "For example, it is estimated that the Midgetman program will need about 50,000 persons for its security requirements."

I am not aware of the source document Dr. Boynton used to make this statement, but the estimate is not correct. As a matter of fact, the Small ICBM program is a "model" program for tackling the specific manpower concerns addressed in the article. Since the Milestone II decision in December 1986, we have vigorously pursued, with both our contractors and HQ SAC (the user), methods to reduce the manpower estimates needed to operate, support, maintain and protect the deployed system. The current program baseline is for 500 missiles deployed at three existing Minuteman bases with two drivers on alert for each HML. The baseline requires approximately 8400 SAC operating and support personnel, 3200 of which provide security. We have identified several opportunities for further reductions in manpower requirements and co-utilization of personnel currently supporting the Minuteman system. These will be evaluated as development continues.

Your periodical is an excellent source of information on the ever changing acquisition world and we, at the Ballistic Missile Office, are prepared to support you and your staff in any future articles.

Respectfully,

William F. Moore
Colonel, USAF
Deputy Program Director
for Small ICBM

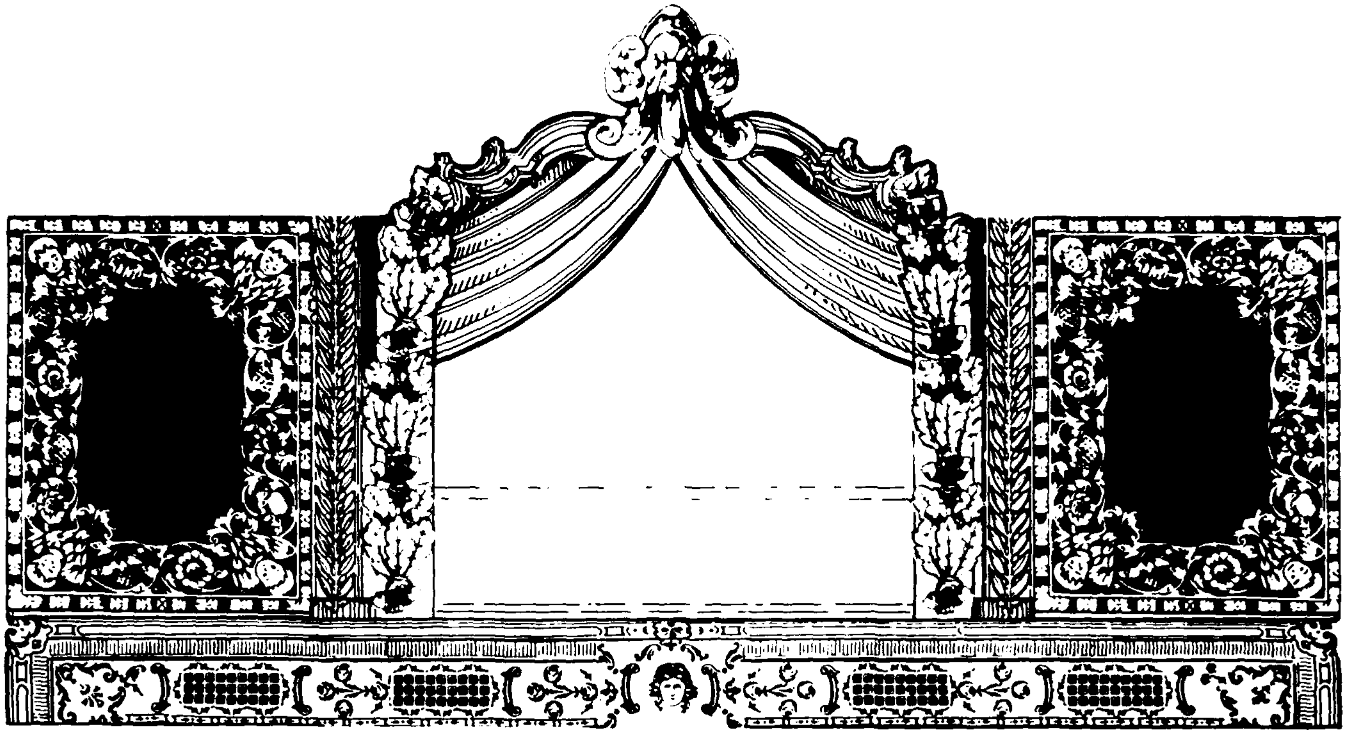
Editors Note: Dr. Boynton presents the following response to Colonel Moore's letter.

May 17, 1989

"Colonel Moore and his project staff are to be congratulated on their efforts to make MPTS, or human factors, concerns a vital part of the development of their missile program. Although not an easy task, it is now a necessary one. DoD Directive 5000.53, "Manpower, Personnel, Training, and Safety (MPTS) in the Defense System Acquisition Process," which was anticipated in the article, was issued on December 30, 1988. Although it applies only to "major" systems, "major" mods and supporting training simulators and devices, the Services have already moved to extend the same requirements to smaller systems and projects.

"The estimate of security personnel was taken from remarks by Alan Ptak. Mr. Ptak was Assistant Secretary of State for Legislative Affairs in May 1988 when the NSIA conference was held. I assume that the estimate was based on his earlier work on the staff of Senator Bill Graham, but the exact source and accuracy of the estimate and the size and operating mode of the program at the time of the estimate were not noted in his remarks. I would like to thank Colonel Moore for his correction and encourage him in his efforts to analyze the MPTS impacts on this program. The real payoff of their concern will come when all program managers include human factors as being co-equal with cost, schedule, and performance as primary program criteria."

Letters to the Editor should be addressed to *Program Manager*, ATTN: DRI-P, Defense Systems Management College, Fort Belvoir, VA 22060-5426. Include your name, address, and daytime telephone number. Unsigned letters will not be used.



SPINNING PLATES
THE ART OF PROJECT MANAGEMENT

Captain Anthony R. Vanchieri, USMC

April 1989

In 1899, the director of the U.S. Patent Office urged President William McKinley to abolish that department. The director said everything that could be invented had been invented.[1] This lack of foresight applied to the entrenched management system, where managers exercised tremendous and absolute autocratic authority of employees. Considered no more than an extension of machinery they operated, employees were slow to receive benefits of current pioneers of management science who saw the need for developing cooperation between labor and management and the propriety of understanding workers' needs.[2]

Who had heard of "project management" 10 years ago? Even today, suppose you are asked: "What do you do for a living?" How do you describe in concrete terms what a project manager does or, more importantly, how you do it.

Picture this. You are performing on a stage before a darkened, packed house. Your act is to spin atop poles as many white china plates as possible. One pole, one spinning plate—another pole, another spinning plate—until, finally, the stage is full of spinning plates. You sprint to all points to keep plates from falling; but, the task is too much for one person and more plates wobble and threaten to fall. Perhaps you should have planned better. Perhaps you should have enlisted helpers. As you are dismissed by the stage manager, the truth hits home: You have been baptized under fire.

Welcome to the world of "spinning plates"—the art of project management.

Occasionally, all project managers feel they share the same fate as that "plate spinner" when trying to manage concurrent tasks. However, the savvy project manager knows the art lies not in managing the *task* but managing the *system*.

Project management cannot exist in a closed system and, in fact, *is* a system that incorporates planning, organizing, staffing, leading and controlling. These separate the total project manager from the crowd.

Managing a specific product is different than managing a system that *is* the product. Project managers seeing progression of their products from conception to completion during discrete stages operate in a different management style than project managers operating within a continuum of events where the "product" is not an object but a service. My product is of this "service-product" category and, as a former "plate spinner," I speak of experience gained the hard way—from lessons learned.

The Quantico Air Facility is a small- to medium-size airport capable of 45,000 flight operations annually. Completely autonomous, it incorporates employee housing, dining facilities, all aircraft support, and buildings and grounds maintenance. The airport conducts long- and short-term planning for growth, is responsible for enforcing and monitoring Occupational Safety and Health (OSHA) standards, and environmental conservation and hazardous material handling policies. As the assistant logistics officer, my department is responsible for ensuring day-to-day continuity of these functional areas.

LESSON 1

Carefully select subordinates, delegate authority, accept responsibility, support limited autonomy, encourage decision-making participation.

Since no manager can be an expert in all functional areas, it is important to let each technical expert in the functional area do his job. By rejecting "traditional" assumptions that suggest employees avoid responsibility, and by encouraging a participative management[3] style, I have created an atmosphere where employees feel a sense of responsibility within their work environments. Delegating authority and supporting autonomy encourage employees to think, and have helped to develop maturity and decision-making abilities of junior managers. Using a wide span of management, you can tap an entire spectrum where employees have more informed opinions than managers lacking first-hand experience.[4]

LESSON 2

Establish challenging yet attainable goals, reward superior performance with added responsibility.

Goal setting, an excellent management tool, leads to more difficult goals, which are usually accomplished with greater productivity.[5] Because my management span is necessarily broad, effective measurable and quantifiable intermediate goals aid me in being able to correct drifting away from desired results.[6] This allows for developing constructive feedback which generates intrinsic self-satisfaction when individual functional departments realize their combined efforts have a synergistic effect. Working in concert, departments achieve results superior to individual effort.[7] Employees achieving beyond established goals may be asking for greater responsibility without knowing it; granting higher levels of responsibility allows the best employees to surface and assume leadership roles.

LESSON 3

Positive reinforcement —eighth wonder of the world.

Recognizing a "job well done" brings employees to center stage with the core of my employees. Sincere recognition of employees and junior management is the critical variable in the success of a program.[8] Positive reinforcement instills pride and self-awareness, which are reinvested in loyalty and dedication.

LESSON 4

If the proof is in the pudding, when is dessert?

Employees and junior managers benefit daily from my management system which is a pyramid: broad at the base and narrow at the top. At the base are functional departments accomplishing day-to-day operations. Near the top, my department directs total effort by benefit of the whole picture using planning, organizing, staffing, leading and controlling; implementing subordinate selection, defining limits of delegation of authority and autonomy, setting goals, and monitoring performance and positively reinforcing superior effort.

The "pudding"—the result—is a dynamic system responsive to, and responsible for, its environment which has been able to achieve a continuum of operation. Each diverse department within this airport is directed by a common game plan that reflects a singleness of purpose to achieve excellence within a complex, multi-faceted system. The common taskmaster is the unity achieved through total project management.

(See Vanchieri, page 28)

WHAT'S HAPPENING IN RESEARCH AT THE DEFENSE SYSTEMS MANAGEMENT COLLEGE

Lieutenant Colonel David Scibetta, USA

The Research Directorate, Department of Research and Information, is the focal point for conducting non-policy-related acquisition management research at the Defense Systems Management College (DSMC). Through individual and joint efforts of five permanent researchers, the 3-4 military officers assigned for a 1-year Research Fellowship Program, and a Research Assistant, the College conducts management research with college faculty and staff and with outside contractors. We also solicit topics from key Department of Defense acquisition officials and the private-sector acquisition community. We begin the process approximately 9 months before the start of each fiscal year.

The military Research Fellowship Program recently completed its initial 1-year term for three selected Army, Navy, and Air Force officers. Visiting research fellowships ranging from 6 weeks to 1 year have proved valuable for individuals from the Department of Defense and other government agencies during the past year. A summary of some ongoing FY89 projects are noted in the following paragraphs. Please feel free to contact any of the noted individuals if you have questions by telephoning Autovon 354-3385 or Commercial (703) 664-3385.

Two researchers, Mr. David Acker and Dr. Franz Frisch, are managing a study, *Capability of Commercial Manufacturing Facilities to Convert to Defense Production*. A contract was awarded in June 1989. The study concentrates on identifying problem areas and potential solutions to foster United States defense production and improving existing mobilization capabilities.

Research Fellows

In June 1989, the three military Research Fellows completed a joint research project, *Commercial Practices Applicable to Defense Acquisition: A Total Quality Management Initiative*. The report compares industry program management practices; documents successful commercial projects; extracts selected useful and innovative techniques in functional areas (e.g., project management, system engineering, quality, financial management, and contracting); and identifies inhibitors that are correctable at the Department of Defense or Service policy level and makes recommendations to implement change. This report is scheduled to be distributed to many Department of Defense agencies in August 1989. The new Service-selected Research Fellows will be on board in early August 1989.

Mr. Calvin Brown is managing a study of commercial practices that may be applicable to defense acquisition of equipment, systems, or services. This study will complement the Research Fellows' project with a broader look at this issue as it affects guidebook illustrating concepts and strategies for selecting and applying those commercial practices in defense acquisitions. A contract is scheduled to be awarded in August 1989 with a 10-12 month performance period.

Knowledge-Based Retrieval Systems

Dr. Robert Ainsley, Education Research Team, and Ms. Sharon Fitzgibbon, Business Management Department, are working with the Microcomputer Systems Laboratory, University of Illinois, regarding the use of knowledge-based retrieval systems. The effort focuses on instructional lesson design and the use of instructional technologies within the Systems Acquisition Financial Management (SAFM) Course at DSMC. The Developing Program Funding Requirements Lesson was identified as the pilot lesson. The class was taught during the SAFM Course in April 1989. Research is being conducted to demonstrate the utility and degree of effectiveness of emerging technologies and lesson design on immediate and long-range learning retention.

The Analytic Sciences Corporation (TASC) completed a contract with DSMC (COR, Dr. Frisch) titled, *Integrating Industrial Preparedness into the Acquisition Process*. Part I explains Industrial Preparedness Concepts and the Industrial Structure. Part II compares 15 selected topics with issues and actions. Each topic is cross referenced to the applicable regulations and discussed in detail.

Dr. Rolf Clark, Mr. James Abellera, and Mr. Michael Otegui continue their joint project on sources of instability in defense acquisition. Dr. Clark is incorporating Mr. Abellera's new research findings on unit costs and Mr. Otegui's analysis of budget dynamics into a simulation model that ties together the relationships among assets, fiscal needs, and acquisition instabilities. Dr. Clark is preparing a paper explaining these dynamic interactions. Mr. Abellera completed his second phase on historical procurement funding instability indicating that unplanned program cuts and hikes reduced the Department of Defense overall weapons output from 1977-87 at a compound annual rate of 3-5 percent. Cumulatively, instabilities may have reduced potential weapons production by more than 20 percent during the decade. Mr. Abellera also prepared a graphical report describing individual unit-cost histories, 1976-87, for three-dozen major programs.

Sponsors MIT National Model

The Department of Research and Information is a sponsor of MIT's National Model. Dr. Clark published an article in the January-February 1989 *Program Manager*, "A Dire Future? MIT's National Model Predictions," that summarizes new MIT insight into understanding national economic trends. The Institute of Cost Analysis invited Dr. Clark to present this paper at its April 1989 luncheon.

Dr. Clark published an article in the *System Dynamics Review* entitled, "Projecting the Future Value of a Variable in a System Dynamics Model." This theoretical article describes how a simulation can "look ahead" to the future, and use that future to affect current decisions in a computer-based model.

The *Managing Quality and Productivity in Aerospace and Defense Guide* was released in March 1989. This new guide was designed to provide management teams and leaders in the defense and aerospace acquisition community with state-of-the art concepts, theories, strategies, and techniques associated with quality and productivity management. The guide is the product of a five-phase, multiyear study involving a diverse group of contractors, academicians, military service acquisition elements, and OSD and DSMC representatives. Mr. Acker managed this effort and guided Virginia Tech, the principal contractor.

Manufacturing Management Guide

The third edition of the *Defense Manufacturing Management Guide* is available. This comprehensive revision was accomplished under the management of Mr. Acker and Lieutenant Colonel Sammie G. Young, USA. It will replace the current 5-year old handbook.

The Defense Systems Management College, in association with the National Contract Management Association (NCMA), will conduct an Acquisition Research Symposium at the Hyatt Regency Hotel - Capitol Hill, October 17-19, 1989. Norman Augustine, Chairman and Chief Executive Officer of Martin Marietta will deliver the keynote address. Abstracts have been received on a variety of topics and the symposium promises to be an exciting experience. Points of contact are Mr. Acker and Mr. Brown.

Lieutenant Colonel Scibetta is the Director of Contract Management and the Acting Director of the Research Directorate at the Defense Systems Management College.

VANCHIERI

(Continued from page 26)

No longer is there a lone "plate spinner," but a team of "plate spinners" under careful direction. That director is the project manager.

The Twentieth century has seen enormous technical and social changes, and we managers have come a long way. There is still a touch of "Patent Office Director" in some of us, urging abolition of new or different management techniques. There are lone "plate spinners" trying to go it alone while plates crash around them. Growing ranks of professional managers, wise to what makes a successful project manager, are willing to develop professionally to become that total project manager.

Endnotes

1. Donna Hussain and K. M. Hussain, *Information Processing Systems for Management* (Homewood, IL: Richard D. Irwin, Inc., 1985), p. 97.

2. Harold Koontz, Cyril O'Donnell and Heinz Weihrich, *Management: Eighth Edition* (New York: McGraw-Hill Book Company, 1984), p. 45.

3. Marlow, A. J., and David G. Bowers and Stanley E. Seashore, *Management by Participation* (New York: Harper and Row, 1967), p. 26.

4. Koontz, O'Donnell, and Weihrich, p. 463.

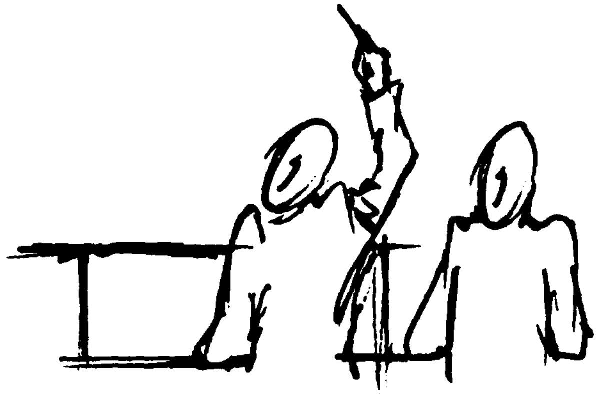
5. Potter, B. A., *Turning Around: Keys to Motivation and Productivity* (Berkley, CA: Ronin, 1983), p. 231.

6. Odiorne, G. S., *Management by Objectives: A System of Managerial Leadership* (New York: Pitman Publishing Corp., 1965), p. 60.

7. Blanchard, K., and Spencer Johnson, *The One Minute Manager* (New York: William Morrow and Co., Inc., 1982), p. 44.

8. Organ, Dennis W., *The Applied Psychology of Work Behavior: A Book of Readings*, (Plano, Texas: Business Publications Inc., 1983), p. 141.

Captain Vanchieri, a helicopter pilot stationed at the Quantico Marine Corps Base Air Facility, is the assistant Logistics Officer.



YOU CAN ONLY TEACH WHAT YOU KNOW

Dr. Franz Frisch

We can not disseminate the knowledge of the Industrial Base if we do not know the structure or the *anatomy* of the industrial base. Hence, we teachers must first acquire the knowledge before sprinkling words of wisdom upon eager students. Our lack of knowledge about the industrial base is widely recognized.

The Defense News, September 26, 1988, in reporting on an *Air Force Association Study noted*, "We found that a lot we thought we knew was wrong, then we were shocked at how much about our own defense industrial base we don't know."

The Industrial Base is the sum of all activities contributing to the supply of industrial products. Resource activities encompass all raw materials, sources of energy and of knowledge, and the work force. Process activities include all facilities, from the smallest workshop to the largest factory, making the industrial products. Finally, transaction activities embrace all distribution systems and all financial institutions supporting the functioning of the Industrial Base. These three groups are interconnected.

Systematic Research

Only if we are willing to conduct systematic research about the industrial base can we hope to understand it. In July 1988, I drafted a paper, "Notes on Industrial Base Research," which outlined a long-range research plan and a research structure dealing with Industrial Base issues. The report, including an outline of 44 research topics and appropriate research recommendations, has an orientation and nine interrelated notes. The orientation provides observations on past research activities and explains drivers for the present collection of notes as outlined below.

—**Nature of Research.** Clarifies "research" and identifies three types: Result Research, which deals with well-defined problems; Knowledge Research, which searches for cause-effect relationships in all cases where the problem definition is vague and uncertainty exists; and, Formalistic Research, when methodologies are newly applied to supposedly known problems.

—**Research Structure.** Develop a master plan for all research activities related to industrial base.

—**Industrial Objective Function.** Ultimate objectives of any industrial enterprise, regardless of size and nature, relate to quantity, quality and price. *Combinations of these factors* provide 27 possible industrial objectives.

—**Industrial Power Assessment.** Every industry has a specific potential for growth. This potential can be assessed by the five prerequisites: control, facilities, knowledge, people, and resources.

—**Industrial Structure (Produce and Process).** Every end-product can be described uniformly with six levels: system, subsystem, components, parts, material, and raw material. At each level, specific manufacturing processes are taking place with a certain amount of value added. Building an end-product starts with level 6, the raw material, and progresses to level 1, the system.

—**Demand and Supply.** Terms of "industrial clusters" and "process clusters" are introduced to underscore the non-uniformity of the Industrial Base. Both clusters are connected with a sketch of the "business link" between product and process.

—**Market Power.** Addresses the question about the power, or lack thereof, to control industrial aspects of the product. Relationships among source, seller and buyer are summarized in a tree structure.

—**Industrial Environment.** This framework is the environment of the industry. The system can influence, but not control, the environment.

—**Research Projects.** A total of 44 research topics are collected. A network will be developed to show the interaction, sequence, and possible efforts involved with each project.

Toward a Curriculum: Outcome (Learning Goal)

Questions in the development of a curriculum must be: What result do we expect? What do we expect from the future Industrial Base specialist? Do we expect a new Renaissance man for the new Industrial World? Do we expect somebody who understands all industrial aspects of law, engineering and economy and who can blend this knowledge with management and politics?

I suggest that we try to make the Industrial Systems Architect (ISA) the outcome of our educational effort. Industry describes the area of his concern; System points toward the interaction of all parts concerned; and Architect used in its original meaning as the planner of the total.

Industrial Systems Architects should have at least a B.S. degree in engineering plus 30 years experience in a broad engineering discipline, preferably industrial engineering. Such "animals," however, rarely exist. Hence, education *must substitute for experience*, and courses that can do this must be developed. I call this new course "Engineering for Non-Engineers."

What Can Be Done?

"Engineering for Non-Engineers" concerns physical possibilities and requirements for physical processes and physical products. The course focuses on a value-free basis of "what can be done" and not with "what should be done," which is value-loaded, and cannot be answered without a value system.

The two other courses of the superstructure are "Law for Non-Lawyers" and "Economics for Non-Economists." "Law For Non-Lawyers" should be concerned with topics of particular interest to the industry and include the following topics: comparison between legal principles as embedded in the Common Law and the Codified Law World, and trade laws and comparison of trade laws in the industrial world.

"Economics For Non-Economists" is a mixture of microeconomics, macroeconomics, engineering-economy and geopolitics. Some sample topics are: general theory of cost and cost behavior for industrial enterprises; comparative profit definition; economy of substitute material; and reliance on foreign materials.

What result do we expect? What do we expect from the future Industrial Base specialist? Do we expect a new Renaissance man for the new Industrial World?

Catching Up

Depending upon background, the student will have to take "catch-up" courses. A student untouched by engineering may have to take a course in manufacturing, which gives more detailed insight than the course "Engineering for Non-Engineers." Let's call it Manufacturing-Extension. This should include some of the following topics: The design process, status of manufacturing, work force, facilities and equipment planning, material management, and total quality management. In other areas, extensions may be appropriate on the military procurement process, government regulations for acquisition, or competition in government contracting.

Assume that the eager student of Industrial Systems Architecture has finished the appropriate courses and, to fill the "holes" in his knowledge, has taken a series of extension courses like manufacturing and engineering economy. He still does not know how the parts fit together and how to utilize his knowledge elements. Therefore, we have to develop courses for integration and application. I call these two courses Industrial Anatomy and Industrial Decision Processes.

Industrial Anatomy deals with the structure and function of the industry. It explains the structure of industrial processes and the product driven interaction among the processes. Industrial Anatomy analyzes the functional structure of processes and products, its possible organizational structures and the ownership structures. It permits one to calculate the impact of changing factors of production to a product, and explains where decisions can be made and where decisions must be made; it permits one to calculate the impact of decisions, but the Industrial *Anatomy does not recommend* the nature of the decision.

Choosing the Topics

Topics for a course on Industrial Anatomy include: micro-aggregate model of industrial activities, value added structure of industrial products, generic work breakdown structure (WBS) of industrial products, functional process structure, and organizational product structure and variation in ownership structure.

Industrial Decision Processes, the value-driven counterpart to the value-free industrial anatomy, goes from the decision process for the individual factory to the political economy at the national and international levels. Some appropriate topics for this course are: planning and analyses of manufacturing investment, foreign sources and political power structures, structural internationalization and structural demobilization, exchange rates and international product structures, and internationally driven logistics.

(See FRISCH, page 31)

Susan J. Palumbo

COST/SCHEDULE CONTROL SYSTEMS CRITERIA
The Management Guide to C/SCSC
Quentin W. Fleming
(Probus Publishing Company, Chicago, Ill., 1988)

On Dec. 22, 1967, the Department of Defense (DOD) issued DOD Instruction 7000.2-Performance Measurement for Selected Acquisitions. It specified 35 detailed criteria with which any firm doing business with the DOD on contracts of a certain size must comply or run the risk of being passed over for new military contract awards. The acronym for these guidelines is C/SCSC, which stands for Cost/Schedule Control Systems Criteria (also referred to as "CSPEC," "Earned Value," "CS Squared," "Performance Measurement, " and simply "The Criteria"). Before implementation of C/SCSC, defense contractors, who often deal simultaneously with more than one customer, were frequently expected to respond to a variety of diverse management requirements from different procuring activities. This imposition made internal and external tracking of performance extremely complex. The United States Air Force took action in 1964 to develop formal requirements dictating that the data from a contractor's own internal management control systems must be the primary source of planned and actual cost/schedule information. Some project managers had already implemented this informally; however, once the decision was made to formalize the requirement, a set of management system characteristics was established. These characteristics formed the basis for development of the C/SCSC.

The primary purpose of the criteria is to provide visibility of accomplishment on each contract. The C/SCSC approach is a significant improvement over the old conventional "budget versus actuals" method. The concept of "Earned Value" requires the quantification of work progress, using objective indicators of work performed. By focusing on work actually accomplished during a given period, realistic assessments can be made of cost and schedule performance. Managers no longer have to guess whether or not contract performance objectives will be met, and they are able to predict and act on potential problems.

It is important to note that the criteria do not represent a "system" or "technique," but rather contractor requirements to employ management control systems for cost/schedule planning and tracking, and provide timely and auditable data for use by both contractor and customer project/contract management. Because of the broad range of contractors, programs, and contract phases, the criteria are intended for broad interpretation and not meant to be overly restrictive. Procuring managers only require assurance that costs and schedule are being managed properly, and that early identification of problems or potential problems is provided.

This book is an updated version of a previous edition already considered by many to be the definitive text on this subject. The author, Quentin Fleming, is employed by a major defense contractor and is well qualified to create such a text. He has deliberately chosen an informal writing style to render a somewhat complex subject relatively easy to understand. His relating of "war stories" and his unique insights into the intent, implementation and effects of the C/SCSC, as well as the inclusion of a complete appendix of U.S. Government and C/SCSC documents, make this interesting, instructional and a valuable desktop resource for system users and practicing and aspiring project managers.

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FRISCH

(Continued from page 30)

Recommended Actions

The following recommended actions are submitted as a potential means to develop the expertise outlined in this paper.

—Develop samples of a job description for future ISAs and employment opportunities.

—Search university curricula for existing appropriate courses and start a collection relevant to the Industrial Base.

—Refine course outlines and designate responsible coordinators for each course segment.

—Familiarize the course coordinators with customary procedures and requirements for the introduction of new courses into a graduate curriculum.

—Discuss incorporation of ISA curriculum into interested departments (i.e., Engineering, Economy, Business, etc.) and determine possible student potential.

—Start the public-relation activity rolling by forming an ISA-Society, preparing symposiums, and informing industrial societies, etc.

Finally, as *sine qua non*, find a high-level U.S. and Canadian sponsor with sufficient political horsepower to push the industrial systems architect (ISA) concept toward realization.

NOTE: This paper summarizes a larger study delivered by Dr. Frisch to the North American Defense Industrial Base Organization (NADIBO). Dr. Frisch, who has been researching the Industrial Base for more than 20 years, notes it continues to change and is so comprehensive that almost any activity could have a place in it.

Dr. Frisch is a Professor in the Research Directorate, Defense Systems Management College.

DETERMINANTS OF CONTRACTOR
PRICING STRATEGY

O. Douglas Moses

The acquisition of major weapon systems is time-consuming, complex and expensive. During the process, particularly contract negotiation, the Department of Defense and defense contracting firms pursue strategies to achieve their (perhaps conflicting) objectives. One element of a contractor's strategy is pricing: the pattern of prices charged for units procured over time. Do unit prices decline as more units are procured or do unit prices remain fairly stable? We feel understanding which factors influence contractor pricing strategy may be useful to contracting officers and program managers involved in the acquisition process.

This articles concerns three issues regarding pricing strategy.

First, we discuss *what* pricing strategies a contractor may pursue; two alternative strategies, penetration and skimming, and features of each are described.

Second, *how*, even when prices are tied contractually to costs incurred, a contractor can adopt a particular strategy; the basic argument is that contractors can use accounting procedures to influence measurement of costs. Evidence relating accounting procedures and pricing strategy is reviewed.

Third, we address reasons *why* a contractor may adopt a particular strategy, suggesting that choice of pricing strategy is influenced by features of the program being considered and features of the larger environment in which acquisition occurs. Evidence on what factors do effect pricing strategy is presented in the context of an analysis of strategies used by defense contractors within the *aerospace industry*.

Two Pricing Strategies

There are many ways to describe or categorize pricing strategies in general, but firms introducing new products or technology typically use one of two product pricing approaches: penetration or skimming.[1] Discussed by many authors, the two strategies are widely understood and used by business practitioners. Objectives of the two strategies differ. The skimming strategy calls for high initial prices followed by lower prices at later stages. Objective of the skimming strategy is to achieve maximum profit in the short run by charging the highest price the market will bear. Thus, one advantage of skimming is a more rapid return on investment.

In contrast, the penetration strategy calls for a low initial price with little or no price reduction over time. Objective of the penetration strategy is to gain entry and establish a position in a market through a low initial price. Once the market has been captured, the firm can take advantage of either price increases or cost reductions to earn additional profits. The firm's established market position dampens incentives of competitors to enter the market.

Each of the strategies can be described in terms of the relationship between two variables: the price of the first unit sold and the rate of price reduction over time. Skimmers exhibit a high first unit price and a steep price reduction curve, while penetrators exhibit a low first unit price and a flat price reduction curve. Neither strategy is inherently more profitable and both are observed in practice. The two strategies do differ in the timing of profits (short-term versus long-term) and, consequently, in riskiness.

With a high initial price, skimming maximizes short-term returns and provides a more rapid recovery of funds to finance costs of product introduction and future expansion. By front-ending profit, skimming reduces risk associated with uncertainty in the product's market. Skimming allows for greater flexibility; it is typically easier to introduce a product with a high price and then reduce the price than it is to introduce at a low price and increase the price later to cover unexpected costs or exploit product popularity.[2] Skimming emphasizes short-run profits and, consequently, reduces risks associated with predicting future demand and future costs.

The penetration strategy sacrifices short-run profits in an attempt to capture the market and generate profits over the long run. Penetration generally requires a greater commitment of the firm's resources, because its long-run orientation may require greater investment in productive capacity, and because the required investment may not be adequately financed from relatively lower initial profits. "Attempting to take a sizeable (market) share through lower price is risky and often requires a heavy and long commitment of financial resources."[3]

"High rewards are possible with this strategy but only if economies of scale occur as predicted. Therefore, it is often a high risk strategy as well, since the potential exists for disastrous losses if costs fail to decline as rapidly as expected. Production problems or unrealized sales volumes can also undermine this strategy."[4] Penetration appears to be the more risky strategy.

Price Reduction Curves

As indicated, the two pricing strategies can be described in terms of the relationship between first unit price and the subsequent price reduction curve. Learning curves can be fit to a series of prices to characterize the pattern of price reduction and, thus, be used to distinguish the two pricing strategies. Learning curve theory describes the decline in per-unit production costs a manufacturer experiences with increasing volume. A per-unit reduction can be extended conceptually to the measure of price per unit. Thus, learning curves can be used to represent price reduction curves.[5]

The learning curve function relates a dependent variable (price) with an independent variable (volume) as follows:

$$P = AX^B$$

Where P is the average price per unit to produce X units; A is the price of the first unit produced, and X is the cumulative number of units. The exponent B is the "index of learning." B is zero if unit prices remain unchanged and negative (positive) if prices decline (increase). It is useful to transform B into the "slope" of the learning curve (S), where B and S are related as follows:

$$S = 2^B$$

A slope of 1.00 implies no price reduction, while slopes above and below 1 imply price increases and decreases, respectively. Unlike B, S has a readily interpretable meaning. A slope of .90, for example, means that the average price for the first two units is 90 percent of the price for the first unit; the average price for the first four units is 90 percent of the average price of the first two units, etc. In short, with a doubling of units, average price is reduced by 10 percent. Relatively low values for S imply a high rate of price reduction. Relatively high values for S imply little price reduction. In short, there is an inverse relationship between slope values and the rate of price reduction.

In following parts of this study, we used slopes of learning curves fit to actual prices to reflect pricing strategy. Relatively high values for S (flat slope) are consistent with penetration, while lower values (steeper reduction) are consistent with skimming.

Accounting Policy and Pricing Strategy

Clearly defense acquisitions, particularly for major weapon systems, are specialized in nature. The market for defense systems is unusual, with a single (monopsonistic) buyer and usually only a few (oligopolistic) sellers. Readers familiar with defense contracting may question the ability of manufacturers to exercise a pricing strategy on major weapon systems. Prices are determined primarily by competitive bids. A bid is accepted and a contract for a specified number of units is negotiated before production. Prices are specified in the contract and based on costs incurred ("cost plus") using some agreed upon formula. Furthermore, cost estimates and their source must be disclosed at the time of contract negotiation, so some agreement on the validity of cost estimates is established up front. Hence, prices may seem to be a direct function of costs incurred, with little leeway allowed for contractor pricing discretion. However, discretion enters through the determination of "cost." Accounting procedures may be used to "cost justify" different pricing strategies.

The Cost Accounting Standards Board (CASB) has specified procedures to guide the accounting for costs of items produced for the government. The objective of the CASB was to provide for uniformity and reduce the area of discretion and judgment involved in accounting for costs on government contracts. That objective has in part been achieved; but specifying narrow rules and procedures to cover all possible circumstances is not possible (or desirable, as the effort involved in such an undertaking would be prohibitive). Consequently, CASB standards provide general guidelines, and flexibility necessarily continues to exist within the guidelines. Standards for dealing with the treatment of home office expenses (#404), general and administrative expenses (#410), engineering costs (#420), service center costs (#418), cost of money associated with facilities (#414, 417), depreciation methods (#409), capitalization criteria (#404), and inventory methods (#411) allow a manufacturer to choose among different acceptable procedures or approaches in determining "cost." The acceptable approaches allow flexibility with respect to: allowability, which costs can be assigned to a particular project or contract; and timing, in what period particular costs will be recognized as incurred. Standards regulating the allowability of costs permit a manufacturer discretion in assigning costs to projects and, consequently, ability to influence the actual cost of a project. Flexibility permitted in determining the allowability of cost is not of central importance in this paper.

Instead, the concern is the timing of costs. When will costs be recognized, assigned to projects and be included in the measurement of manufacturing cost per unit? Accounting procedures that assign cost to different periods permit the recognition of costs earlier or later. Such inter-period allocation of costs are necessary under generally accepted accounting principles when expenditures benefit activities of the firm during more than one accounting period. Earlier recognition of costs would be associated with higher unit cost for the first units produced, and lower unit costs for later units, resulting in decreasing average unit cost over time and apparent cost reduction. Delaying cost recognition would result in a relatively lower unit cost for earlier units produced but less apparent cost reduction.

There are many assumptions and judgments involved in accounting which could potentially involve inter-period allocation of costs. As examples, let's focus on three specific situations covered by the Cost Accounting Standards Board and look at the potential effect on cost reduction of accounting choices made within the constraints of the Board's standards.

Depreciation

Standard #409, "Depreciation of Tangible Capital Assets," requires that manufacturers choose depreciation methods consistent with those used for financial reporting, and that support be developed for reasonable estimates

TABLE 1. MANUFACTURER ACCOUNTING METHOD CHOICES

CONTRACTOR	AVERAGE SLOPE	DEPRECIATION METHOD	INVENTORY METHOD
Boeing	.869	Accelerated (1)	Average (3)
Republic	.742	Accelerated (1)	LIFO & Average (2)
Gen. Dyn.	.781	Accelerated (1)	Average (3)
Grumman	.829	Accelerated (1)	LIFO, FIFO, Ave. (3)
Vought	.879	Straight Line (5)	LIFO (1)
Lockheed	.825	Accelerated (1)	Average (3)
Martin	.991	Accelerated (1)	FIFO (5)
McDonnell	.865	Accelerated (1)	FIFO, Average (4)
Northrop	.885	Both (3)	FIFO, (5)
North American	.870	Both (3)	LIFO, FIFO, Ave. (3)
Bell	.928	Both (3)	LIFO, FIFO, (3)

of asset service lives. The effect is to permit a manufacturer to spread the cost of tangible capital assets acquired for, or used on, a particular program over the units produced in accordance with any of the popular depreciation methods. These include (but are not limited to) straight-line, sum-of-years-digits and declining balance. An accelerated method choice will cause relatively more cost to attach to units produced early in a program and relatively less to the latter production. Flexibility enters in choosing depreciation method and estimate of useful life.

Assume a project lasts 5 years (periods). Assume a capital asset with depreciable cost of $10,000 is used for 5 years on a project. If straight line depreciation were used, depreciation cost per period for each of the five periods would be as follows: 1) $2,000; 2) $2,000; 3) $2,000; 4) $2,000; and 5) $2,000. If accelerated (sum-of-the-years digits) depreciation were used, costs per period would be: 1) $3,333; 2) $2,667; 3) $2,000; 4) $1,333; and 5) $667. Thus, apparent reduction in per-unit cost is achieved via choice of an accelerated depreciation accounting method rather than any real difference in cost incurrence.

Capitalization or Expensing Of Costs

Standard #404, "Capitalization of Tangible Assets," requires that manufacturers establish policies for capitalizing costs associated with assets and provides guidelines for those policies. If cost is capitalized, it is treated as an asset, presumed to benefit several accounting periods, and the cost is spread over those periods. The alternative to capitalization is immediate expensing, in which case the cost is assigned to the current period in which the expenditure occurs.

A manufacturer is required to designate a minimum sevice life criterion (2 years or less) and a minimum cost criterion ($1,000 or less). Asset costs shall be capitalized when both criteria are met. Assume Manufacturer A sets a policy of capitalizing items which cost more than $1,000 and have a service life of more than 1 year. Assume Manufacturer B sets limits of $500 and 2 years. An asset costing $750 with a service life of 5 years would be capitalized by B and expensed by A. An asset costing $1,500 with service life of 18 months would be capitalized by A and expensed by B. In short, manufacturers have some ability to influence the timing of costs through the designation of capitalization criteria.

The manufacturer may designate other characteristics pertinent to this capitalization policy; e.g., class of asset, identifiability, integration or independence of constituent units. Assume a manufacturer has a policy of capitalizing items with cost in excess of $1,000. A personal computer costing $750 and a printer costing $500 are acquired. If the two items are considered independently, neither would be capitalized If the two items are considered jointly to be a single computer system costing $1,250, then the full $1,250 would be capitalized. In short, manufacturers have additional ability to influence the timing of costs through the manner in which costs are classified or grouped.

Let's return to the $10,000 cost incurred in the previous section on depreciation. (Assume straight line depreciation). Assume also that 10 percent of the $10,000 ($1,000) involves asset costs which may be either capitalized or expensed depending on the capitalization policy. If the $1,000 is expensed, the remaining $9,000 would be subject to depreciation and spread over the five periods at $1,800 per period. Thus, two cost series could result. Capitalization: 1) $2,000; 2) $2,000; 3) $2,000; 4) $2,000; and 5) $2,000. Expensing: 1) $2,800; 2) $1,800; 3) $1,800; 4) $1,800; and 5) $1,800. Note that here the capitalization alternative shifts costs to earlier periods and results in apparent cost reduction over time, again with no real difference in the actual incurrence of costs by the manufacturer.

Material Costs

Standard #411, "Accounting for Acquisition Cost of Material," provides guidelines for accounting for materials in inventory. Inventory accounting methods provide another means by which inter-period allocation of cost can be controlled. This is particularly true when there is inflation. A manufacturer may elect, with certain restrictions, to use the first-in-first-out

(FIFO), the last-in-first-out (LIFO), the average cost method, or some combination of these in assigning cost to production. Under FIFO, material costs are assigned to production using "older" acquisition costs. Under LIFO, material costs are assigned using "recent" or current acquisition costs. Total costs assigned to production over the life of a project will be the same under FIFO and LIFO; LIFO, relative to FIFO, will result in costs being shifted toward the earlier periods because, given inflation, LIFO results in earlier recognition of the rising costs of materials. Again, varying patterns of apparent cost incurrence can be achieved when there is no difference in real cost incurrence.

Associations Between Accounting Policies and Price Reduction Slope

Objective of this discussion is to suggest how accounting choices made by a contractor could, through timing of costs, effect the pattern of costs and prices realized on a project. Are accounting procedure choices related to the pattern of price reduction observed on real projects? In a study published in *Program Manager*,[6] Greer provides some evidence. His analysis is summarized here, with minor modification. Greer collected price history data for a sample of major military aerospace programs (e.g., F-15A, A-7D) manufactured for DOD by 11 contractors. He determined price-reduction slopes using learning curves for each program, and then determined an average price reduction slope for programs manufactured by an individual contractor, by calculating the mean of the slopes on the various programs produced by each contractor. Table 1 lists contractors and average slopes, and accounting methods for depreciation and inventory, taken from 1982 annual reports, for the 11 contractors.

Numbers beside accounting choices in Table 1 represent a ranking of the allocation effects of the methods. An accelerated depreciation method will cause relatively more cost to attach to units produced early in a program. A value of one was assigned to accelerated depreciation. Straight-line produces the opposite result; this method choice received a five. Companies, like Northrop, which use both accelerated and straight-line, were assigned a three. Analogously, LIFO causes earlier recognition of costs of materials; so LIFO received a one, FIFO a five, and average cost a three. Combinations were weighted linearly.

These accounting policies can be viewed in two ways. First, they are direct indicators of the depreciation and inventory methods adopted by the manufacturers in question. Second, they may be indirect indicators of the tendency of the firms to use accounting methods that recognize costs relatively earlier or later. Depreciation and inventory policies are "visible" methods in that they are disclosed in annual reports. Capitalization policies and other techniques that may be used to influence the allocation of costs to periods are not visible. Research indicated that firms do not select accounting methods independently of each other, but choose methods jointly to achieve their goals, and knowledge of one method used by a firm may provide information on others because firms tend to exhibit individual corporate personalities.[7] Perhaps the visible methods substitute for non-visible accounting influences.

Given expected impacts of accounting policies on price-reduction slopes, one would hypothesize a positive association between average slopes and accounting method codes. Table 2 provides simple univariate pair-wise correlations between slopes and codes. Non-parametric Spearman correlations were used because codes used to represent the methods are at best of ordinal scale. Results are generally consistent with expectations: Depreciation methods and inventory methods are positively associated with slopes at reasonably significant levels.

To control for interrelationships between the accounting methods, a regression model was constructed using average slopes as the dependent variable and the method codes as independent variables. This procedure assumes cardinal scaling for the method choices, which is not the case, so results must be relied on with caution. In any event, findings (Table 2) are consistent with the correlation tests; both variables are significant with the expected positive signs. The adjusted R^2 value of .404 suggests that even relatively crude knowledge of accounting method choices can be used to explain a fair proportion of the variance in slope values.

TABLE 2. ASSOCIATION OF PRICE REDUCTION SLOPES WITH ACCOUNTING METHODS

CORRELATIONS	DEPRECIATION	INVENTORY	INTERCEPT
Corr.	.576	.447	
Significance *	.032	.084	
REGRESSION			
Coefficient	.027	.041	.679
Significance *	.033	.014	

F value: 4.39
Model significance: .052
R^2: .523
Adjusted R^2: .404

* one tailed tests

The conclusion is that, even when prices are tied to costs, a contractor has some ability to influence price-reduction curves through accounting policy; hence, some ability to pursue a pricing strategy even when prices must be cost justified.

Why Pursue a Pricing Strategy?

If the acquisition of a particular defense system by the government occurred at a single point in time under a single unchangeable contract covering all units of a weapons system to be procured, the ability of a manufacturer to influence unit price through the measurement of cost would be of little importance; shifting costs from earlier units produce to later units (or vice versa) would have little impact on the total costs and price for the complete output produced. But features of the acquisitions environment preclude the use of a single, unchangeable contract covering all units to be manufactured during a weapons system acquisition program.

First, due to the complex nature and state-of-the-art technology involved in major weapon systems, contracts are frequently updated or revised to accommodate design and production changes. Revision of an individual contract provides the manufacturer the opportunity to renegotiate price and profit. Second, because of the nature of the federal budget process, funding for units procured under a weapons system program is reviewed and approved on an annual basis. Consequently, system acquisition typically occurs in several stages under several different contracts. This letting of new contracts provides the manufacturer the opportunity to renegotiate.

A potential contractor on a new weapons system has two alternatives. The firm can submit a high bid (e.g., skim by setting a high price for initial units produced), which tends to ensure profitability and the recovery of invested funds in the short-run, but has the disadvantage that it increases the probability that a competitor will secure the contract. Or, a firm can submit a low bid in an attempt to penetrate or buy-in to the initial contract to capture the market (sometimes at an initial loss), and presume that subsequent contract revision or renegotiation or future contracts will result in satisfactory profits in the long-run.

The penetration strategy would appear to be more risky. The complexity, innovation, and high-performance requirements associated with major weapon systems mean their capability and reliability cannot always be assessed in advance. This creates uncertainties about product acceptance and the future demand for more units by the Department of Defense. Furthermore, the constantly changing economic and political environment creates uncertainties about willingness of the Congress or the Executive Branch to budget for more units. This results in uncertainties about program curtailment or termination. Technical, political and economic consideration affect Department of Defense readiness to revise or renegotiate existing contracts. Finally, possibility of second-sourcing creates uncertainty about the number of units to be procured from the original contractor in the future, as well as the price that may be obtained. This factor has become more important with the increased emphasis on competition in recent years.

Observation of a low initial price indicates a willingness by a contractor to commit resources to a program with the possibility of only relatively low short-term profits, or even a loss. A low initial price signals a willingness to bet on the future and accept risks of program curtailment of termination, uncertainties involved in trying to increase price if contracts are revised, uncertainties associated with future procurement contracts, and accompanying uncertainties associated with long-run profit realization.

It might be argued that a skimmer has a greater risk of losing the contract; however, this would be an inappropriate use of the term. Risk implies uncertainty, not probability. It is true that a skimming strategy increases the probability of losing a contract; but, what a skimming strategy really signals is an unwillingness to place a bet on the uncertain future, an unwillingness to play the game unless success is assured through locking in profits in the short-run by setting the price high initially. A reluctance to play unless success is assured is consistent with risk-averse behavior and fully consistent with penetration being a more risky strategy.

Neither strategy is inherently more profitable, although they may differ in the timing of the realization of profits. When would a contractor adopt one strategy instead of the other? When would a contractor have an incentive to buy-in with a relatively lower initial price and accept the greater risks associated with the penetration strategy? In the next section are factors we felt had the potential for influencing contractor pricing strategy.

Influencing Factors

Two broad concerns should influence contractor pricing strategy: the nature of the specific program under consideration and the nature of the political or economic environment existing at the time of the contract negotiation on the program.[8] The variables listed should reflect some program feature or some environmental feature. We have tried to suggest how each variable might influence a contractor's willingness to compete by reducing initial price; and hence, why *it might be associated with pricing* strategy.

Program Value. Obtaining a contract for a major new weapons system is a significant event for a firm. Jobs are created and future profits are expected. We felt a contractor's willingness to compete on price for a new program would be related to the program's value to the firm, and expected that a penetration strategy would be more likely with higher value programs. Program value was measured by total cost of the program over its life.

Program Length. Obtaining a contract for a program that is expected to extend for several years has distinct benefits for a firm. Facilities costs can be amortized over longer periods. Revenues can be expected to continue for several future periods. We felt willingness to compete on initial price would be influenced by the number of years a program was expected to run.

and expected that a penetration strategy would be more likely with longer-term programs.

Program Size. As argued, contractors may be more willing to compete on price for high-value programs. Another factor may come into play. If an individual program is small relative to total operations of a firm, experiencing unexpected costs and losses on the program, while damaging, would not be critical. In contrast, greater risk is incurred if a program comprises a substantial portion of a firm's total operations. Unfavorable performance on the contract could have significant implications for the performance of the firm as a whole. Consequently, when a program is large relative to the contractor's total operations, we expected that contractors would be less willing to accept a low initial price and, instead, reduce risk by pursuing a skimming strategy. We measured program size relative to firm size by dividing the average yearly value of a program by the contractor's total sales.[9]

Defense Spending. What was the congressional and budgetary environment when programs were negotiated? Were constraints being imposed on defense spending? Were non-defense programs favored? Was defense spending increasing? We felt contractors would have less incentive to reduce initial price if the environment appeared to be favorable to defense spending; hence, a skimming strategy would be expected. Two variables were used to reflect the defense spending environment:[10] Defense spending as a proportion of total federal spending, which indicates relative budget emphasis between defense and non-defense federal programs, and rate of growth in defense spending, which indicates changing commitment to defense programs over time.

Industry Conditions. To the extent that an individual firm's facilities are currently being employed, incentives to compete for defense work in general, and for a specific new defense contract in particular, may be lessened. Such firms may feel in a strong position to bargain for a higher initial price. More generally, when facilities within an industry are being fully employed there may be reduced incentive for all firms to compete for additional work, and less concern that a particular competitor will offer a low price to secure a program. In short, pricing strategy may be associated with current utilization of productive capacity within an industry. We expected the penetration strategy to be more likely when capacity utilization is relatively low.[11] Two variables were used to reflect the industry environment: percent of industry capacity utilization, which indicates current industry conditions; and the rate of growth or decline in capacity utilization, which indicates the trend in industry conditions.

General Economic Conditions. Perhaps economic conditions, growth or contraction, influence pricing strategy. If the economy is robust, demand for products should be relatively greater, opportunities for commercial projects may be more plentiful, and incentives to compete on initial price for a particular defense contract may be reduced. Consequently, a skimming strategy may be followed. When economic contraction occurs, new defense programs may appear more appealing and the increased incentives to compete for such contracts may result in a penetration strategy. The rate of growth in the Gross National Product (constant dollar) was used to reflect economic conditions.

Inflation. This makes future dollars worth less than current dollars. If inflation is high, firms may prefer to adopt a pricing strategy leading to rapid returns on a new project. As indicated, neither skimming nor penetration is an inherently more profitable strategy but skimming, with higher initial prices, tends to lead to more rapid returns and earlier recovery of funds. Consequently, we expected skimming to be associated with an environment characterized by relatively greater inflation.

Commitment to Program. There is inevitably some uncertainty concerning the long-run government commitment to individual weapon systems. Long-run plans may be made, but the federal budget is discussed and revised annually. Programs supported one year by an Administration or the Congress may be cut in subsequent years as conditions change. To the extent that long-run commitment to a particular weapon system is doubtful, contractors may have incentives to seek relatively higher initial prices to reduce future risks of program curtailment; i.e., to skim. If commitment to a program is not in question, contractors may willingly buy into a contract, having more confidence that program curtailment will not threaten returns expected in future years. Commitment to a program is not readily measured but funds allocated to a program, as reflected in annual obligational authority, may provide an indication of the government's willingness to commit to the program. Early allocation of funds may reflect a strong initial commitment. We divided the initial year obligational authority for a program by the total obligational authority over the life of the program, creating a measure reflecting a proportion of the project that was funded up front. We expected this measure of early commitment to be associated with a penetration pricing strategy by contractors.

Acquisitions Environment. The environment in which military acquisitions occur has not remained static. The phrase, military-industrial complex, was unfamiliar before Dwight D. Eisenhower left the presidency, but awareness of the links between the Department of Defense and the defense industry is pervasive, and a symbiotic relationship has developed between the Department of Defense and the defense industry. There are many stories of cost overruns. Scrutiny of the acquisitions process by the Congress and the public has increased. Calls for increased competition are heard. Oversight, regulations and procedures governing acquisition have been revised and altered over the years. Have these changes had consistent effect on pricing strategy? To the extent that increasing scrutiny of defense acquisitions have motivated contractors to compete for defense work by offering lower initial prices, one might expect that penetration strategies have increased in recent years. If the Depart-

TABLE 3. SUMMARY OF VARIABLES

VARIABLE NAME	ABBREVIATION	MEASURE
Program Value	PVALUE	Total cost of program over its full life
Program Length	PLENGTH	Number of years program ran
Program Size	PSIZE	Average yearly value of program divided by contractor size (sales)
Defense Spending	DEFSPND	Defense spending divided by total federal spending
Defense Spending Growth	DEFGRO	Rate of change in Defense spending
Capacity Utilization	CAPU	Percentage of Aerospace industry capacity utilization
Capacity Utilization Growth	CAPUGRO	Rate of growth or decline in industry capacity utilization
Economic Growth	ECONGRO	Rate of growth or decline of GNP
Inflation	INFLA	Inflation rate measured using the producer price index-industrial
Funding Obligated	FUNDS	Initial obligational authority for a program divided by total *obligational authority*
Calender Year	YEAR	Year of initial production on program
Follow-on Program	FOLLON	Whether or not a program was a new model of a previously produced system

ment of Defense is more dependent on individual contractors, if weapon system technology is more complex and uncertain (creating the opportunity for contractors to demand subsequent price increases to cover unexpected costs), and if contractors are more powerful and successful in demanding price increases, one might expect an increasing use of penetration strategies in recent years. It is possible to document whether there has been a general trend toward more or less use of one pricing strategy or the other. A variable indicating the calendar year in which programs were initially undertaken is included in the analysis to capture any general trend.

Follow-on Programs. Because price-reduction slopes are used to reflect pricing strategy, one more variable was included in the analysis as a control. While pricing strategy should affect the slope of the price-reduction curve on a given project, pricing strategy is not the only factor influencing the slope. When a project is the first production model of a weapon system, some learning and some reduction in unit price can be expected over time. When a project is a "follow-on," a new model of previously produced item, less learning and price reduction should occur. For example, Lockheed produced the P-3a and P-3b. One would expect a flatter price-reduction curve (higher slope) for the follow-on P-3b model. A variable (FOLLON), coded 1 if the program was the first production model of a weapon system and 2 if a follow-on model, was included in the analysis to capture this probable effect on price-reduction slopes.

A summary of variables are included in Table 3. In the following sections, we provide evidence that the anticipated relationships among many of these factors and contractor pricing strategy tend to exist.

TABLE 4. SAMPLE PROJECTS

PROJECT	CONTRACTOR	YEARS	SLOPE
F-102A	General Dynamics	53-57	.724
F-100D	North American	54-56	.934
F-101A/B/C	McDonnell Douglas	54-59	.802
F-8A/B/C	Vought	55-58	.831
A-4B	McDonnell Douglas	55-57	.834
F-104A/B/C	Lockheed	56-57	1.154
B-52G	Boeing	57-59	.869
F-105B/D	Republic	57-62	.759
F-106A/B	General Dynamics	57-59	.837
A-4C	McDonnell Douglas	57-62	.894
F-8D/E	Vought	58-63	.882
F-4A/B	McDonnell Douglas	59-66	.834
P-3A	Lockheed	60-64	.718
AIM-9C	Motorola	61-67	.961
RIM-8E	Bendix	61-66	.916
A-6A	Grumman	61-69	.829
RIM-2D	General Dynamics	61-64	.976
RIM-2E	General Dynamics	61-66	.921
RIM-24B	General Dynamics	61-66	.923
A-4E	McDonnell Douglas	61-64	.892
F-4D	McDonnell Douglas	64-66	.886
A-7A/B	Vought	65-67	.852
P-3B	Lockheed	65-67	.910
RIM-66A	General Dynamics	66-70	.763
RIM-67A	General Dynamics	66-74	.825
A-7E	Vought	67-79	1.000
A-37B	Cessna	67-73	.935
A-7D	Vought	68-75	.950
P-3C	Lockheed	68-82	.972
AIM-7F	Raytheon	68-80	.773
A-6E	Grumman	70-79	.937
F-111F	General Dynamics	70-74	1.115
F-14A	Grumman	71-82	.990
RIM-66B	General Dynamics	71-80	1.135
S-3A	Lockheed	72-76	.846
F-15A	McDonnell Douglas	73-79	.917
RIM-67B	General Dynamics	73-82	1.041
AGM-78D	General Dynamics	73-75	1.088
AH-1S	Bell	75-80	.891
A-10A	Fairchild	75-82	.963
AH-1T	Bell	76-78	1.021
F-16A	General Dynamics	78-82	.954
F/A-18A	McDonnell Douglas	79-82	.860
AIM-7M	Raytheon	80-82	.880
RIM-66E1	General Dynamics	80-82	1.089
BGM-109	General Dynamics	80-82	.943

Aerospace Weapons Programs

We investigated pricing strategy for major military aircraft and missile weapon systems acquired by the Department of Defense from 1953-80. Data on prices, and specifically price-reduction slopes calculated using learning curves (based on constant dollars), were collected from two publications: *U.S. Military Aircraft Cost Handbook* and *U.S. Military Missile Cost Handbook*.[12]

The handbooks provide data for numerous weapon system programs, which had to pass three filters to be included in the study.

First, programs had to run at least 3 years to calculate meaningful slopes.

Second, programs that were duplicates were eliminated. For example, price histories for the A-7A and A-7B were available individually and combined as one program. The combined history was used, the individual programs were not.

Third, programs where learning curves fit to the raw price data provided a poor "fit" were eliminated.

Since the purpose here is to explain variations in price-reduction curves, only programs with well-defined price-reduction slopes were included. An R^2 value in excess of .6 was used as a cutoff for program inclusion. The remaining group consisted of 46 programs. Program identifiers, the manufacturer, the year of program initiation and price-reduction slopes for the 46 programs are provided in Table 4.

TABLE 5. CORRELATIONS WITH PRICE REDUCTION SLOPES

VARIABLE	EXPECTED SIGN	CORRELATION
PVALUE	+	-.11
PLENGTH	+	.18
PSIZE	-	-.33*
DEFSPND	-	-.34**
DEFGRO	-	-.42**
CAPU	-	.18
CAPUGRO	-	-.42**
ECONGRO	-	-.12
INFLA	-	.18
FUNDS	+	.37**
YEAR	+	.38**
FOLLON	+	.36**

* p> .05
** p> .01

Correlation Analysis

In general, our objective was to determine if explanatory factors outlined earlier explained variation in price-reduction slopes consistent with our predictions. As a first step, we correlated each variable independently with price-reduction slope. Expected signs (assuming the factors are related to pricing strategy in the way we anticipated) and actual correlations are in Table 5. Several findings are interesting. Seven of the twelve variables are significant at traditional significance levels and each of the seven has the predicted sign.

These initial findings suggest that programs of larger size (PSIZE) may motivate skimming. Skimming appears to be encouraged when defense spending is great relative to total federal spending (DEFSPND), when defense spending is growing (DEFGRO) and when industry capacity utilization is growing (CAPUGRO). A penetration strategy seems to occur when initial funding for a program is great (FUNDS). There has been a general trend toward penetration pricing during the last three decades (YEAR). As expected, price reduction is less evident for follow-on programs (FOLLON).

Multivariate Tests

While multivariate correlations provide insights, perhaps a fuller story can be told by controlling for possible inter-relationships of explanatory variables in a multivariate model.

We used stepwise multiple regression to create a model including several variables jointly explaining variance in slopes. Stepwise regression is a statistical procedure adding one variable at a time to a model depending on which variable most assists in explaining the variable of interest, in this case price-reduction slope. By selectively influen-

TABLE 6. A MULTIVARIATE MODEL

VARIABLE	COEFFICIENT	t-VALUE	SIGNIFICANCE
Intercept	.337		
FOLLON	.053	2.25	.003
FUNDS	.356	3.93	.001
PLENGTH	.008	1.95	.058
DEFGRO	-.188	-2.05	.047
YEAR	.006	4.03	.001

F Value: 8.19

Significance level: .0001

R-Square: .51

Adjusted R-Square: .44

TABLE 7. CORRELATIONS BETWEEN EXPLANATORY VARIABLES

	PLENGTH	PSIZE	DEFSPND	YEAR	INFLA	DEFGRO	CAPU	CAPUGRO	ECONGRO	FUNDS	FOLLOW
PVALUE	.27	.34	.15	-.07	-.10	.12	-.11	.03	-.14	-.20	-.36
PLENGTH		-.20	-.17	.12	-.15	.18	.12	-.19	.11	-.48	.10
PSIZE			.57	-.12	-.55	.23	.13	.41	-.20	-.01	-.16
DEFSPND				-.93	-.54	-.08	-.01	.03	-.21	.19	-.09
YEAR					.68	.25	.07	.00	.19	-.13	.12
INFLA						.32	.20	.25	-.09	-.12	.08
DEFGRO							.66	.65	.42	-.05	.14
CAPU								.47	.42	-.11	.23
CAPUGRO									.40	.07	-.03
ECONGRO										.08	-.05
FUNDS											.12

cing the entry of variables into the model during the stepwise procedure, a researcher has some control of the model that results, and gains insight into the interrelationship of explanatory variables, and their relative ability, to explain the dependent variable. In short, stepwise regression is a method of exploration.

We investigated various models in a heuristic and iterative fashion. We were concerned with two qualitative factors in constructing the model:

1. Parsimony: We preferred a model with few variables.

2. Lack of interrelationship of explanatory variables: High correlation between pairs of variables or high "collinearity" among several variables in a model causes coefficients to be less meaningful and the model to be less useful for prediction.

We considered three statistical items to determine when we had arrived at a "good" model:

1. The overall significance of the model (F value).

2. The significance of individual ratios in the model (t statistics for ratio coefficients).

3. The explanatory power of the model (adjusted R-squared values). Table 6 provides detail on a representative model. Looking at the table, several items are of note: The model is highly significant and has a reasonably high R^2 value. It explains about half of the variation among contractors in price-reduction slopes. Each of the five variables included in the model is significant with the predicted coefficient sign.

Interpretation of the Model

In general, the model demonstrates that pricing strategy is significantly associated with factors reflecting features of the program or the contracting environment, and suggests that attention to these factors may be useful for detecting contractor pricing strategy. A relatively small collection of variables appears to explain a fair amount of variation in price-reduction slopes.

The individual explanatory variables in the model are of interest but taking a look at interrelationships of explanatory variables is necessary for a more complete interpretation. Table 7 provides pairwise correlations of explanatory variables. In general, correlations are relatively low, with the exception of correlations within two subsets of the variables (enclosed in the triangles). The DEFSPND, YEAR, INFLA and PSIZE are interrelated. The high positive association between INFLA and YEAR is not surprising; it is well known that inflation was higher in the 1970s than in earlier decades. In retrospect, the high negative association between DEFSPND and YEAR is not surprising; growing emphasis on social programs, starting in the 1960s, has reduced the proportion of government spending devoted to defense programs. (In fact the very high correlation between DEFSPND and YEAR suggests that these two measures are almost substitutes for each other.)

Similarly, DEFGRO, CAPU, CAPUGRO and ECONGRO are positively interrelated. This is not surprising. General economic growth (ECONGRO) should be reflected in growth within the aerospace industry (CAPUGRO). General economic growth should make defense spending growth (DEFGRO) more acceptable, which should be reflected in aerospace industry growth.

When sets of individual explanatory variables are highly associated with each other, they tend to collectively capture some common underlying dimension.[13] Inclusion of one variable in a regression model reduces the chance that another from the same set will provide additional power to explain the dependent variable. With this as background, a better interpretation of variables in the model is possible. The model shows that five factors explain price reduction slopes.

1. Follow-on Programs. Price-reduction slopes tend to be flatter when the program is a new model of a previously produced weapon system. This was expected since the most substantial learning, and cost reduction, should occur during the first production model.

2. Program Funding. Variable FUNDS was one of the most consistently important and highly significant explanations of pricing strategy in all regression models constructed. When initial obligational authority for a program was high relative to the total value of a program, contractors tended to use the penetration strategy. This indicates that the apparent commitment of the government to a program, as reflected in funds initially allocated, impacts contractor pricing. High initial commitment may reduce contractor fear that the program will be terminated or curtailed before sufficient returns can be realized and, by reducing this risk, permit the contractor to reduce initial prices during contract negotiation.

3. Program Length. The penetration strategy was associated with programs that extended for a longer time. Extended programs may benefit contractors by allowing them to lock in revenues for future periods and reduce the costs and uncertainty associated with the level of operations in future periods. Such benefits appear to be reflected in a greater willingness to reduce initial prices.

4. Industry Condition and Outlook. Variable DEFGRO appears in the model presented in Table 6 but, as discussed, several other variables tend to capture the same underlying dimension. Other models were constructed including CAPU or CAPUGRO in place of DEFGRO, with little decrease in explanatory power. Thus, it is probably not growth in defense spending *per se* that affects pricing strategy. Rather, growth in defense spending is associated with higher utilization of industry capacity and expectations of continued industry health. When capacity is adequately being utilized, incentives to compete for new defense projects are reduced. Consequently, skimming pricing strategies are pursued.

5. Trend. Variable YEAR appears in the model presented in Table 6 but YEAR was correlated with other variables, particularly DEFSPND. (DEFSPND could replace YEAR in the model with little effect on explanatory power.) It is clear that the trend during the last three decades has been toward increasing penetration strategy. This could be due to the increasing emphasis on non-defense spending, causing contractors to reduce initial prices to buy into the budget. As indicated, other explanations are possible. Increasing scrutiny of defense acquisitions may motivate contractors to reduce initial price demands, while the increasing interdependence of the Department of Defense and defense contractors may permit contractors to renegotiate later prices, ensuring satisfactory profits. These effects would result in the apparent trend toward penetration strategies.

Final Comment

Our objective has been to describe two pricing strategies available to contractors, indicate how accounting policy may provide a means for contractors to adopt a particular strategy, and provide evidence on the role of factors in motivating the choice of strategy. Our model documented and described the relationship between a set of motivating factors and pricing strategies. Our findings suggest that features of the program and features of the acquisitions environment affect the pricing strategy used by defense contractors. Taken as a whole, the analysis suggests three broad conclusions.

1. There has been a general trend toward buy-in or penetration pricing strategies during the last three decades. This is consistent with the trend toward greater non-defense federal spending motivating contractors to buy into the budget with reduced initial prices.

2. Contractors tend to adopt penetration strategies when initial funding for a program is high and when the expected duration of a program is long. Both factors may provide contractors with some assurance that a program will not be terminated before sufficient returns can be earned and, consequently, permit contractors to reduce initial price.

3. Contractors tend to adopt skimming strategies when defense spending and industry capacity utilization are increasing or when capacity utilization is high. This is consistent with strong demand for the industry's output, lessening contractor incentive to reduce initial price.

Note that this study addresses defense programs during three decades. The acquisitions environment has changed significantly during that period. Today, emphasis is on increased competition in defense procurement. This has been reflected in policies toward increased financing of contractor facilities by the government, with the objective of opening the door to competition and increasing the possibility of second-sourcing. We have competition advocates. Performance measurement of contracting officers incorporate measures designed to reflect the degree to which competition in procurement is achieved. The result of these and other changes in the acquisitions environment suggest that contractors may be facing more circumstances when penetration-type strategies may be necessary to secure contracts. (This is consistent with the general trend toward penetration noted in the sample.) What has changed by the increased competition demanded by the government, however, is the range over which different pricing strategies may be effectively pursued, not the concept of pricing strategy *per se*. It is likely that the incentives outlined in this article still influence contractor actions.

We hope contracting officers, program managers and others involved in acquisition activities gain insight into the pricing practices of contractors from this analysis.

Endnotes

1. For a discussion of pricing strategies see "The Pricing Decision: Part I-The Cornerstone of the Marketing Plan," *Small Business Report*, Vol. 10, No. 5, May 1985, pp. 71-77; Dean, J., "Pricing Pioneering Products," *Journal of Industrial Economics*, (July 1969), pp. 180-187; and Wind, Y. *Product Policy: Concepts, Methods and Strategy*, (Addison-Wesley, 1982).

2. For further elaboration of features of the skimming strategy see Dean, op. cit. and Caferelli, E., *Developing New Products and Repositioning Mature Brands*, (Wiley 1980).

3. Direct Quotation from Caferelli, op. cit., p. 176.

4. Direct quotation from "The Pricing Decision," op. cit., p. 77.

5. For further discussion of learning curves, see E. Deakin and M. Maher, *Cost Accounting*, (Irwin, 1987), pp. 381-385.

6. Greer, W., "Early Detection of a Seller's Pricing Strategy," *Program Manager*, November-December 1985, pp. 6-12.

7. See for example, M. Zmijewski and R. Hagerman, "An Income Strategy Approach to the Positive Theory of Accounting Standard Setting/Choice," *Journal of Accounting and Economics*, August 1981, pp. 129-149; and G. Sorter, S. Becker, T. Archibald and W. Beaver, "Corporate Personality as Reflected in Accounting Decisions: Some Preliminary Findings," *Journal of Accounting Research*, 1964, pp. 183-196.

8. In a related study, K. McGrath and O. Moses investigated the links between pricing strategy and contractor's financial condition. Using a sample of defense aerospace contractors, similar to the sample in this paper, they found that firms with lower financial risk and lower utilization of assets tended to penetrate. See "Financial Condition and Contractor Pricing Strategy," *Program Manager*, September-October 1987, pp. 11-19.

9. Note that these first three variables, (program value, program length, program size), use measures of the actual value of a program and the actual length of a program in their computation. Actual value and length would not be known before completion of the program. In principle, measures of the "expected" value or length of a program should be used to reflect the pricing strategy incentives hypothesized to exist before production commences. Use of the *ex post* actual measures assumes they are reasonable surrogates for *ex ante* expectations. Alternative measures for program value and program size were determined using the initial obligational authority for the programs rather than total costs during the program life. Findings were similar using these alternatives. Constant dollar measures were used for all alternatives.

10. Defense spending was measured 1 year before the start of production on a program. Growth in defense spending was measured during the period from 2 years to 1 year prior. This assumes that measures taken at that time are representative of the environment in existence when contractor pricing strategy was formulated. Other variables designed to reflect industry and economic conditions were measured at analogous points in time prior to the start of production.

11. Contractors may have separate divisions for commercial and DOD work, each being operated, in effect, as separate businesses, with corporate headquarters acting in the role of a bank providing funds to finance projects. Ideally, we would like a measure of the capacity utilization of the DOD division of firms to capture more precisely the incentives that may be operating. Such measures were not readily available. Industry measures provide a rough surrogate. In any event, work by Greer and Liao indicates that industry measures of capacity utilization prove to be better predictors of contractor pricing behavior than do firm specific capacity utilization measures: W. Greer and S. Liao, "Cost Analysis for Competitive Major Weapon System Procurement: Further Refinement and Extension," Naval Postgraduate School Technical Report, NPS54-84-023, Monterey, Calif., Sept. 1984.

12. DePuy, S., et al., *U.S. Military Aircraft Cost Handbook*, TR-8203-1, (Management Consulting & Research, Inc., 1983) and Crawford, D., et al., *U.S. Military Missile Cost Handbook*, TR-8203-3, (Management Consulting and Research, Inc., 1984).

13. A formal factor analysis of the explanatory variables was conducted. The PSIZE, DEFSPND, YEAR and INFLA formed a distinct factor with YEAR having the highest factor loading. Similarly DEFGRO, CAPU, CAPUGRO and ECONGRO form a distinct factor, with CAPUGRO having the highest factor loading. All other variables represented distinct individual factors. Regression models using factor scores rather than individual variables were substantially similar to the model presented in Table 4.

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The second day of July, 1776, will be the most memorable epoch in the history of America. I am apt to believe that it will be celebrated by succeeding generations as the great anniversary festival. It ought to be commemorated as the day of deliverance, by solemn acts of devotion to God Almighty. It ought to be solemnized with pomp and parade, with shows, games, sports, guns, bells, bonfires, and illuminations, from one end of this continent to the other, from this time forward forevermore.

—John Adams
Letter, July 3, 1776

COMPUTERIZED PERT NETWORK FOR DAB PLANNING

Lieutenant Colonel John C. Nicholson, USAF

The process of preparing an executive program for a Defense Acquisition Board (DAB) milestone briefing is imposing, even in these days of acquisition streamlining. The amount of documentation to be provided to the Pentagon is voluminous, and the number of briefings required to get to the final decision briefing is large. Advanced planning activities should begin almost a full year ahead of the DAB to provide high confidence that pre-DAB activities may be accomplished in the normal flow of program office work without supplemental resources.

To improve the key headquarters management functions of advanced planning and process control, the DCS for Systems at Air Force Systems Command proposed that the process of preparing for a DAB IIIA be "captured" and described in a Program Evaluation Technique (PERT) network and loaded into program management software on an office personal computer. The operational concept was to develop a headquarters tool that would assign proper OPR responsibility for DAB preparation activities, would permit routine insight into a program's progress in accomplishing key pre-DAB activities, and most importantly, would permit the early identification of issues so they could be resolved prior to the DAB. The ultimate goal was to achieve more "successful" DAB decisions, in the sense that there would be neither information gaps nor unresolved issues that might cause program decisions to be deferred or based on incomplete or inaccurate information. An additional goal was to facilitate process improvement—the networking project became step one (describe the current process) in implementing a *Total Quality Management* approach to improving this particular portion of the acquisition process.

A prototype of the network was developed by CACI, Inc., a local engineering firm. The Harvard Total Project Manager software package was selected by CACI to implement the network. After conclusion of the CACI effort, a team of several officers spent the next eight weeks modifying and improving the prototype and developing procedures to make it a useful control tool.

Since the network was developed for headquarter use, the nodes/activities which were selected for control (monitoring) were those of specific interest to the functional Deputy Chiefs of Staff at Headquarters Air Force Systems Command. These nodes included all of the key pre-DAB activities across the acquisition functions such as contracting, logistics, test and evaluation, intelligence, manpower, manufacturing and the comptroller area. For example, the comptroller selected several key activities involved with field accomplishment and Headquarters review of the Independent Cost Analysis (ICA).

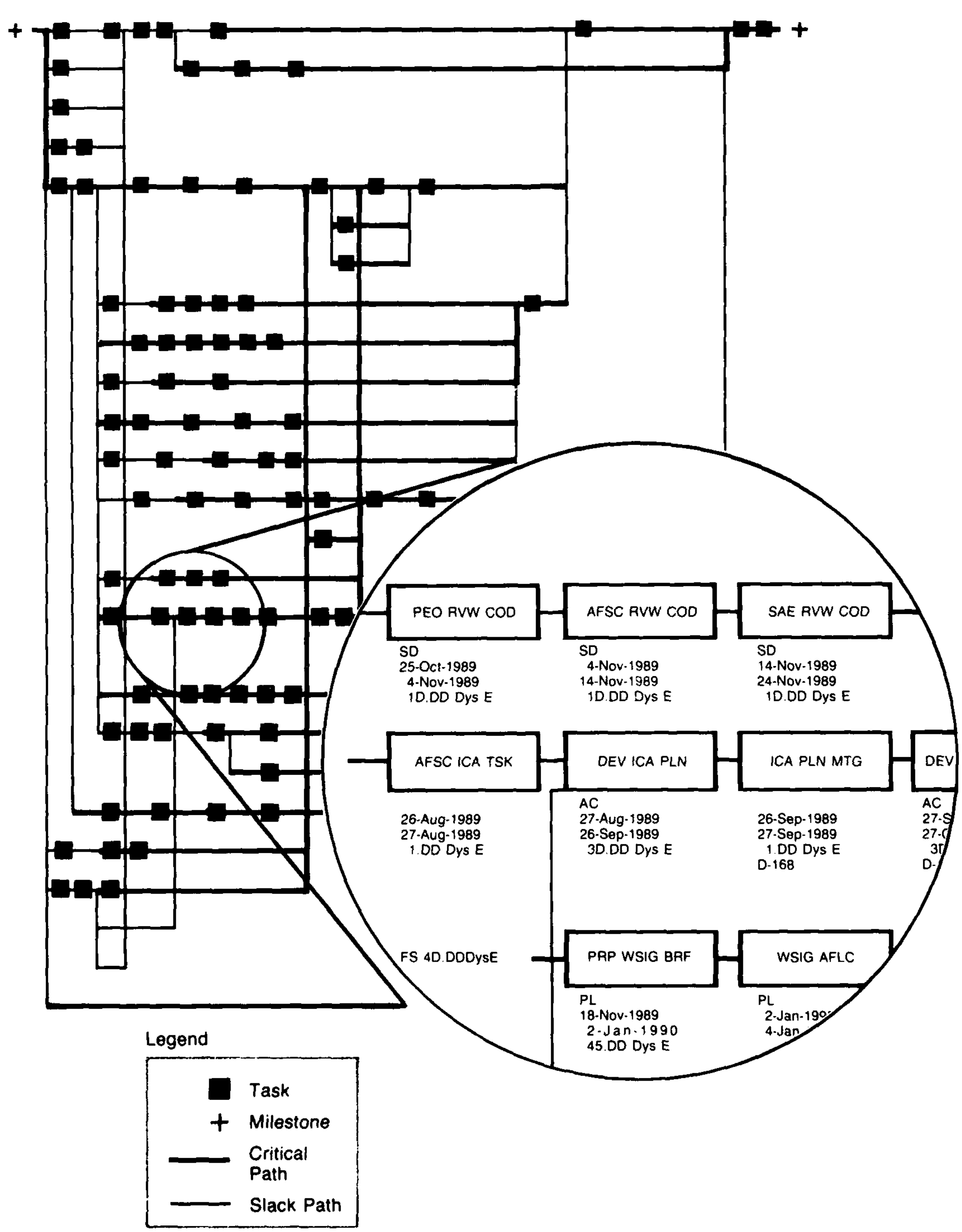
In total throughout the network, 112 nodes were needed to describe all of the key pre-DAB activities, based on 26 documents of law, regulation, and formal policy. The network is tailored to the Air Force and AFSC regulations implementing acquisition directives. In a few instances, activities were placed in the network which have not yet been formally institutionalized throughout the Air Force Systems Command. One example is the accomplishment of an Independent Technical Assessment (ITA), a review still in the process of definition by the AFSC Directorate of Systems Engineering. Notionally, the ITA will assess the degree of technical uncertainty or risk at a point before either the ICA or the Acquisition Strategy Panel are conducted. "Control" as it applies to this activity, then, means asking logical questions such as: "Does this program need an ITA? When must it be completed? Who will conduct it?" Depending upon the answers, this activity either will not be applicable or will be required, planned, and then routinely monitored. In either case, the activity is consciously dealt with, and not forgotten.

What to Monitor

While the network was intended to be used at the headquarters, it should be of interest to program directors of Air Force DAB programs. First of all, it will tell them what the functional Offices of Primary Responsibility (OPRs) at headquarters consider sufficiently important to monitor. Second, it should help program offices avoid having to develop their own DAB planning network. Its use should assist program managers in planning, allocating resources, controlling actions and training new employees in the DAB process. Copies of the generic (non-program-specific) network, either in hard copy form or on disk, are available from HQ AFSC/SDMI, Andrews AFB, MD 20334-5000. Offices wanting the disk version should provide a formatted floppy. Essential documentation will also be provided.

A portion of the network is illustrated in Figure 1. The node name is depicted very cryptically on the plotted network, but the Harvard files contain a more complete (one line) description for review on the computer screen or in an optional report. The descriptive "tags" attached to each network node list the Headquarters Official Primary Responsibility, planned start and completion dates (notional, for the generic network), duration of the activity (again, often notional, but reasonable, based on practical experience), and any suspense date for submission/completion/review which is explicitly required by a regulation or policy. The format for the suspense date is "DAB date minus xx days."

FIGURE 1. PERT CHART: DAB IIIA VERSION 2, PROJECT DAB3AV2



At predetermined, periodic intervals, each program's progress is briefed by the responsible headquarters Director to a Deputy Chief of Staff Executive (General Officer) Review Committee.

In order to make the network more useful for control purposes, a descriptive "action" worksheet was prepared for each node of the network and saved in a dBase III file. This worksheet provides a narrative description of what is intended by the activity/node, and tells who the key players normally are. A sample worksheet is shown at Figure 2.

Start and Finish Dates

Starting with the generic network, it is easy to create program-specific networks. By replacing the generic DAB date with the actual or best available date, the computer will calculate all of the program-unique start and finish dates. Even if the DAB secretariat has not scheduled the DAB, planning dates are normally provided in the Acquisition Decision Memorandum from the previous milestone. We create a specific program file for each program that has a DAB date within the following 12 months. This tailored network is then used to identify those activities that should be started, underway, or finished during any period of time. These activities are flagged for the specific time period being monitored, and the appropriate worksheets are distributed to OPRs to check status and issues. The worksheets are also program unique, to the extent that key SPO and staff OPRs are identified.

It is important to mention a limitation of the network. Neither it nor the worksheets should be used blindly or bureaucratically. In other words, it may not matter whether or not an activity has begun "on time" because many dates are notional, after all. What matters is that the task is understood, there is a plan, commitment and resources to accomplish the activity in time to meet milestones and to resolve issues.

Another limitation, of course, is the external world. There are numerous ongoing critical program activities that are not directly connected to DAB preparation efforts. Basically, the System Project Office (SPO) is trying to accomplish the technical job—the full-scale development efforts. Without question, technical progress and contractor performance have a very real potential for perturbing DAB plans in a major way. Alternate plans may be needed for DAB documentation which is not available, or perhaps invalidated, due to some real-time technical problem. This simply reenforces the need to approach the process in a disciplined manner, and to apply professional judgment in dealing with control of the network.

Checklist to Remembering

Using such a reasonable management approach, network implementation becomes useful even for programs that are already less than the 12 month lead time away from a DAB. In that case, the network becomes a checklist to assure that nothing has been forgotten, and a tool for assessing if the scheduled DAB date can reasonably be attained with a quality product. If the program manager cannot be ready for the DAB on time, it seems prudent to consider rescheduling as early as possible, rather than waiting until the 11th hour.

As part of the DAB network, the Headquarters initiated a specific subprocess to *review pre-DAB progress* at the highest levels, and to assure that assistance in resolving issues is provided in a timely manner. At predetermined, periodic intervals each program's progress is briefed by the responsible headquarters Director to a Deputy Chief of Staff Executive (General Officer) Review Committee. The DAB network incorporates a node for each of these briefings to assure that this subprocess is institutionalized. At the actual briefing, executives assess the information and decide if progress (or lack thereof) in resolving issues warrants their intervention. As time progresses and the DAB draws near, unresolved issues justify intervention at progressively higher levels in the Command. About two months before the DAB, for example, the Vice Commander will get involved to help work tough issues not yet settled. At roughly six weeks before the DAB, the Commander will review the DAB briefing and determine whether he needs to personally intervene.

Even though the final network has been implemented only for a short while, it has proved useful. We have identified that a DAB planning meeting is necessary as early as possible—a year early, if possible. Waiting until 6 months before the DAB (the current OSD target) is too late. The program director should know if documentation can be tailored or waived, for example, or if other streamlining will be allowed before he has to begin expending resources. Deferring this type decision until the 6-month point may lead to expending resources unnecessarily.

Another way in which the network has been of value is in the identification of confusing and conflicting guidance. The contracting community, for example, identified significant confusion about regulatory guidance on dual sourcing, and has begun working with the Judge Advocate General to clarify rules.

FIGURE 2. DAB IIIA PERT NETWORK ANALYSIS (V. 2)

PROGRAM NAME: GENERIC
DAB DATE:03/16/89
Today's date:

NODE: AFSC RVW COD NODE START: 04/14/89

DESCRIPTION:
AFSC REVIEWS COOPERATIVE OPPORTUNITIES DOCUMENT

AFSC OPR: SD

FINISH DATE: 04/24/89

REQUIRED BY: AFR 800-1

KEY PLAYERS:

SYSTO:

PROGRAM DIRECTOR:

PEM:

USER POC:

NARRATIVE:

HQ AFSC/SD COMPLETES COORDINATION OF THE COOPERATIVE OPPORTUNITIES DOCUMENT THRU THE HQ. ALLOW 20 DAYS (NOTIONAL) FOR APPROVAL & FORWARDING TO SAF/AQ. AFSC FORWARDS DOCUMENT.

NOTE: REPORT STATUS WHEN CLOSED, AND RETURN THIS FORM TO SDMA AT THE NEXT 0-5 WORKING GROUP MEETING. IF THE STATUS IS OPEN, DO NOT REPORT. CONTINUE TO MONITOR ACTION UNTIL CLOSED.

STATUS:

The headquarters systems officer for a program with an upcoming DAB (the JTIDS program) reported the network made it possible to provide better assistance to the System Project Office. A required Acquisition Strategy Panel meeting had been overlooked, but was identified with the network.

Finally, members of the Executive Review Committee seem pleased with their new insight and enhanced ability to "weigh-in" on tough issues at an early date.

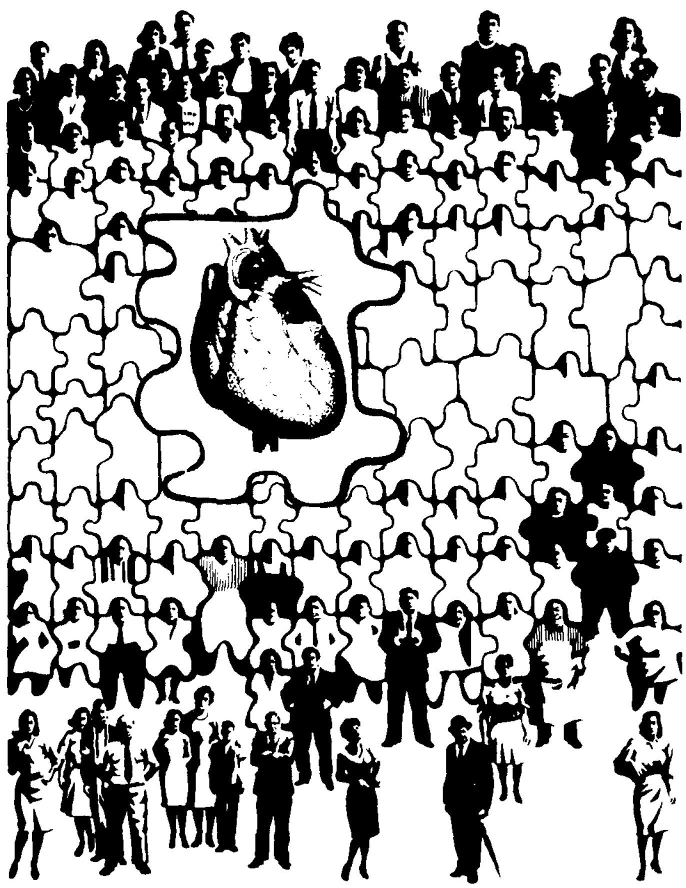
Plans for the immediate future include developing a network for DAB II by using the DAB IIIA network as a template for identifying differences. Each Deputy Chief of Staff is identifying nodes to add or delete to the network to make it accurate for Milestone II. The Deputy Chief of Staff Offices of Primary Responsibility will be providing worksheets for added nodes.

Final test of the network will come later—the first time a DAB is conducted for a program controlled under the network. We are optimistic because we know advanced planning and process control should set the stage for success. We believe "setting the stage for success" is the key responsibility of the headquarters, and one of the best things we can do to help deliver successful programs.

Lieutenant Colonel Nicholson is Deputy Director for Systems Engineering in the DCS for Systems, HQ Air Force Systems Command. He was graduated from the DSMC Program Management Course in 1986.

MOTIVATING EMPLOYEES: THE NATURE OF TRAINING

Geoffrey G. Noyes



Efficiency of an organization depends on how members are trained. Newly hired employees usually need training before their new assignments; career employees require training to keep them alert to demands of current positions and to prepare for possible transfers and promotions.

Training motivates employees to work harder. Employees understanding their jobs are more likely to have higher morale and because management is confident enough of their abilities to invest in training gives assurance they are valued members of the organization. This is particularly important in organizations undergoing changes in technology or methodology. Workers resist changes like automation, fearing they will not be competent to assume newly created jobs. For these reasons, public and private organizations spend enormous monetary amounts on training.

Training at one extreme consists of a few hours or minutes of instruction by a supervisor giving the new employee an outline of organizational policies, location of locker room, and summary of work rules; at the other extreme, training consists of formal courses to develop qualified specialists during a period of years. Between these extremes are programs tailored to fit needs of a particular organization; i.e., short courses on safety and health, customer relations, personnel programs, and drug and alcohol abuse.

It is misleading to think of all job training purely in terms of formal courses and programs. Almost everything happening to an employee after joining an organization is a training experience. The worker learns what is expected in a new situation through experiences; those that are rewarding and provide satisfaction tend to be repeated and those that are not tend to be abandoned.

Many individuals within an organization besides formally assigned trainers provide rewards. The informed work group, with clearly defined codes of behavior, has a potent influence on members and formal groups, such as unions, which exert a strong effect. Many times the supervisor provides training without being aware of it. The acts that provoke or that fail to provoke discipline tell an employee what is expected of him and what he can do with impunity. Good housekeeping practices that are praised and slovenly workmanship that goes uncriticized are sources of training. Similarly, the methods, short cuts, and routines practiced by fellow employees carry important meanings that are assimilated by the novice learning the way in a new work environment.

Training derived from these sources may conflict with the prescribed ways of doing things; but, only sources of information and advice proving most consistent will have the most profound effect on the employee. Management must be careful to ensure that the impact of casual day-to-day experiences does not nullify practices stressed in more formal training sessions.

Who Should Train?

In many organizations, training is informal. It consists of assigning new employees as helpers to other employees, or telling an experienced employee to instruct the new individual. At times, results are excellent but often the established employee fails to train adequately; sometimes this failure reflects indifference or hostility toward breaking in a new employee. Perhaps the career employee feels he isn't being paid to train or that he may be creating a competitor for his position or potential positions. More often, the established employee fails because he is unable to communicate and lacks the systematic knowledge of learning principles.

Management today usually establishes formal provisions for training, either by holding line management directly responsible for training by hiring training specialists, or sometimes both. Occasionally, training specialists report directly to line management but, more frequently, a special training section is established within the personnel department.

As staff experts, training specialists face the problems of staffers everywhere; line management may resent their efforts as interference; they may try to teach employees methods that conflict with those the manager wants used, either because standard organization procedures are not being followed or the trainer has not kept pace with developments in the field. Conflicts often arise when the training specialist insists on telling employees, who are under the direction of a line supervisor, how they should be doing their jobs. Equally unfortunate, once a training specialist has been appointed, the line supervisor may decide to give up all responsibilities for training. Some organizations have tried to create an amicable division of responsibilities by having the staff trainer conduct classes out of the work area and advise the line supervisor on how to conduct better training, on the floor, (in a sense the staff may train the trainer) by holding the line supervisor responsible for all training in the production area.

Sometimes the busy, hard-pressed supervisor tends to neglect what he considers the mere formalities of induction training and concentrates exclusively on the immediate job assignment.

Types of Training Programs

Sometimes, the busy, hard-pressed supervisor tends to neglect what he considers the mere formalities of induction training and concentrates exclusively on the immediate job assignments. Haste and the lack of sensitivity at this early stage will spawn unnecessary personnel problems further on; for example, an employee refusing to do a task claiming it's not part of his job, having never received a complete explanation of his duties.

Progressive organizations have long recognized the need for properly introducing a new employee to the job. Not only do organizations familiarize the employee with tasks to perform but will provide information about rules and personnel policies, introduce fellow workers, and give an idea of where the job fits into the total operation. A carefully planned and motivating orientation for an induction program helps the new employee identify with the organization and its procedures, giving some feeling for significance of the work being performed. This helps overcome fears and anxieties arising from a new job.

Where employee duties are clearly described at the outset, misunderstandings are less likely to develop. Furthermore, proper induction training makes it unnecessary for the employee to "unlearn" methods and procedures that prove unacceptable. Unlearning is difficult and time-consuming.

Realistically, of course, no supervisor can expect to communicate everything about a new job at the outset and some information presented is bound to seem meaningless and confusing to the inexperienced subordinate, who cannot appreciate the significance of what is being said. A link to reinforce induction training and establish a firm foundation for an employee will be directly related to the type of training that is given for progression which, coupled with proper field application, broadens an employee's productivity curve.

Management must decide whether training is to take place in the normal work location or off-the-job; the latter is most effective when the job is difficult, when mistakes or slowness will materially impair production schedules or methods, and where special coaching is required. Sometimes, placing the new employee in certain work environments immediately could endanger his safety, the welfare of others and, possibly, risk damage to costly equipment.

Simulation devices are an invaluable form of training. For instance, computers make it possible to simulate the operations of an entire distribution center, enabling employees to learn to cope with emergencies and make proper responses at minimal cost. In this way, the learner is shielded from pressure of the actual job situation and demands of supervisors primarily interested in production.

Off-the-job training has certain drawbacks. Many skills cannot be learned in slow motion. In effect, doing a task slowly may transform it into an entirely different task. This is particularly true of certain difficult muscular-sensory coordination jobs. Noise and other distractions in the real workplace may be other factors the trainee must learn to accommodate, just as he must master specific body motions and intellectual responses. Finally, off-the-job training is expensive and the employee is being taught by instructors who will not work with him or evaluate his performance when he moves to the actual job.

When an employee fails to meet established standards, performance may signal need for more training. After a while, an employee may forget procedures learned during induction or may develop shortcuts requiring less energy and thought. Management may introduce new procedures and equipment altering the employee's job requirements. Thus, training is not a one-step process; it is a continuing managerial responsibility.

Training employees with some experience on the job may be a more difficult task than giving them induction training; however, old-timers may resent being told they can't do their job or may suspect that training is an attempt to show them up, perhaps for disciplinary reasons or to step up output all at their expense. Telling an employee he needs remedial training may embarrass him before colleagues, which is a threat to status as an intelligent and competent worker.

As an alternative to remedial training for individuals, organizations use regular refresher courses in areas like safety, job methods, and housekeeping. This practice avoids spotlighting the poor performer and may avert the tendency to slip into short-cuts. Periodic training permits regular introduction of new methods and techniques. New accounting practices, new company products, or engineering standards, and new equipment require explanation. If these explanations are presented regularly, the possibility that important changes will be overlooked is substantially reduced.

Training for Advancement

Effective training may help individuals to climb promotional ladders to more responsible positions. Of course, the function of all education is to permit individuals to advance on the basis of merit and ability. Careful ordering of jobs in promotional ladders permits individuals to learn, primarily through observation, some skills of higher-ranked positions while doing their present job. Filling-in for higher-ranked colleagues provides informal on-the-job training.

Many organizations have developed a school program. Organizations employing skilled employees may conduct formal intern programs; here, on-the-job training directed by skilled employees is supplemented by some classroom instruction. Smaller organizations may band together, usually in collaboration with unions and public or private institutes to set up needed programs.

A typical intern program takes from 2-5 years. The school portion of a typical program may include, in addition to career/job related courses, math, science, general business and written business communications, sandwiched into more practical on-the-job aspects. The best programs provide for a rotation among jobs and employers so the intern learns all aspects of the career field. As more occupational groups seek to professionalize and establish experience and examination requirements for members, the intern type of training program should become more widespread and, also, strengthen the organization.

Most fields of knowledge are changing at a rapid pace; teaching, computer or engineering degrees received a few years ago may be obsolete. Further, skills not used regularly on the job are quickly lost, and refresher training is needed. A major policy question is: How much should the organization do to keep employee knowledge and skills updated and how much should the individual do for himself?

The professional must have the time and facilities to keep abreast of his field. If the organization will establish a carefully planned program of continuing voluntary education, coupled with some mandatory training, the conscientious professional will supply his own motivation, which often is the most fruitful. At the same time, management must recognize the ensuing basic conflicts between immediate job demands and continuing professional growth. A plan for tuition rebates and time off may motivate an individual to continue and maintain currency.

Organizations must determine how much and types of advanced training to be used. The most obvious factor is the economics of training. How much can an organization afford to spend on developing employees, who may leave, permitting other organizations to reap the benefits? Because some organizations' needs are acute, they have no choice but to train. Organizations must ensure that wage and salary levels, quality of supervision, and working conditions are attractive enough to retain trained personnel. It cannot be assumed that employees gratitude for training received will outweigh disadvantages; in fact, ambitious employees who are grasping at educational opportunities are most alert to other job offers.

Another policy decision concerns the responsibility an employee will be assigned after successful completion of a training program, particularly if the training is during uncompensated time. Should people taking extra training be guaranteed advancement in preference to people not electing to do so? If so, all employees should be made aware of the policy and its implications.

Resolving questions like these requires that personnel be able to measure contributions of any training effort. On some positions this may simply be to measure production on a before-and-after basis. On other jobs, it is more difficult to measure the performance or contribution of the employee since many people jointly contribute and other factors are constantly changing at the same time training is proceeding. Thus, it is difficult to show that helping an engineer obtain a master's degree improves his work; but management in this, like in other personnel programs, wants evidence that dollar expenditures are providing comparable improvements in operations.

Is the U.S. Government receiving comparable improvements through the tremendous dollar expenditures for training?

Mr. Noyes was an Instructor, Reutilization and Marketing Committee, School of Materiel Readiness, U.S. Army Logistics Management Center, Fort Lee, Va., when he wrote this article.

TASK FORCE INITIATIVE
(DSMC STUDENTS HEAR MG HENRY)

Lieutenant Colonel Bruce Sweeny, USA

Major General Charles R. Henry, USA, presented a current Office of the Under Secretary of Defense (Acquisition) task force initiative, "Improving the Acquisition Process," initiated in November by Dr. Robert B. Costello, former Under Secretary of Defense (Acquisition). The task was to learn how to incentivize contractors to reduce costs. The task force addressed many improvements, prepared a report, briefed the Defense Acquisition Executive and Service Acquisition Executives and obtained permission to systematically brief the buying activities DOD-wide. They will complete a final report with recommendations in October 1989. The task force comprises senior procurement executives of the Army, Navy, Air Force and the Defense Logistics Agency (DLA). 1

Major General Henry described the substance of the initiative which is guided by principles listed below. 2

Provide Total Quality Management

—Use long-term contracts to provide a stable base.

—Recognize best contractor performers; DCAS pre-award survey data base to become available to source-selection officials.

—Review MIL Q-9858A requirements for contractor quality programs.

—Improve configuration control and technical data packages (e.g., ensure engineering change proposals (ECPs) applied before recompeting; recompete using level II vs. III technical data packages (TDPs). 6

—Solicit Could Cost proposals from long-term established best contractors; use gainsharing to mutual advantage.

—Institute total quality management profit incentive policy wherein profits are based on performance versus costs, and again use gainsharing. 8

Buy Best Value

—Develop a fast-track for prescreening and announcing results at competitive open solicitation; this may preclude some companies from investing in a proposal if they are not likely to be competitive; their savings may improve investment in independent research and development. 9

—Announce intent to award on initial proposals; no multiple best and finals.

—Reduce multiple proposal and contract extensions.

—Award to best value contractors, guaranteeing technologically superior performance. 11

—Be aggressive in eliminating poor performers; revise progress-payment approach to ensure contractor is delivering, not just spending. 12

Reward Best Value Producers

—Use total quality management profit incentive policy.

—Redefine progress payments.

—Increase progress payments to best value producers.

—Reward primes developing small/disadvantaged businesses with additional 1 percent profit.

—Reduce administrative requirements to get better value and use less DOD review (e.g., eliminate cost/pricing data on best value contractors and competed contracts). 17

—Revitalize value engineering; make it easier on contractors to propose value engineering proposals; speed-up review and decision cycle time. 18

—Give "The World" feedback on best value producers; Secretary of Defense or Deputy Secretary of Defense to send out results soon. 19

The Buy Best Value approach has been approved for development by the Office of the Secretary of Defense, the Services and the Defense Logistics Agency with each member taking the lead on a subset of the above elements. Expected results include a more business-like approach to Department of Defense buying, getting more modernization out of lower defense budgets, and reducing the cost of defense to taxpayers. 20

Major General Henry said, "we must be a better customer—a world-class customer." 21

Lieutenant Colonel Sweeny is a Research Fellow at the Defense Systems Management College.

Thomas W. Doeppner

COMMAND, CONTROL, AND COMMUNICATIONS -- SYSTEMS ENGINEERING

Walter R. Beam
(McGraw-Hill Book Co., New York, 1989)

Dr. Walter R. Beam, Professor of systems engineering at George Mason University, was a senior civilian staff member in the Office of the Secretary of the Air Force, and later a Vice President of Sperry (now Unisys). This book is a product of his 15 years of involvement with command, control, and communications (C^3) systems. 1

The book is of particular interest to program managers, as there exists hardly any modern major military system that is not critically dependent on the proper use of the electromagnetic spectrum for effective command and control, and reliable, timely communications. It is a refreshing, easy-to-read, surprisingly inclusive text on the *systems engineering* aspects of C^3 systems. *It is unique in its clarity of* writing, in the author's ability to focus on the important central aspects of a subject, and in its mathematical simplicity. 2

Each chapter includes a challenging set of exercises. These range from relatively straightforward mathematical problems (e.g., to show the shape of contours in radionavigation), to more subjective ones such as developing cost-benefit arguments for repair-vs.-discard strategies in system maintenance. 3

The first four chapters lay out the pieces of C^3 systems, starting with a short tutorial on wired and wireless communications including antenna principles, propagation characteristics, and radio-noise considerations. The treatment moves up to box-level communications: switches, transmitters and receivers, and digital processing. Use of computers in C^3 systems is treated at some length. 4

Chapter 4 deals with military C^3 elements, managing to stay away from classified areas without undue gaps in coverage. There is a major section on radars, and a section on electronic warfare. Chapter 5, the last dealing mainly with hardware, takes up special technologies like navigation systems, earth satellites for surveillance and communications, and data fusion. 5

The subsequent treatment of systems engineering is somewhat nonconventional, in breaking life-cycle issues first along functional lines: Chapter 6 describes "structure and dynamics" of C^3 systems, using examples from military and business organizations. Life-cycle issues are pointed out, along with some "special design considerations" which include several important C^3 system requirements. 6

Chapter 7 deals with the subsystem level of design, and illustrates one of the strengths of the author's approach: *don't overlook the "obvious."* An example: "...one should not ignore simple face-to-face conversation," which precedes a discussion of intercoms in noisy cockpits. There is a brief section on electromagnetic compatibility (EMC), which is unfortunately considered inadequately, or too late, in too many of our system acquisition efforts. 7

Chapters 8 and 9 deal with human-system issues and available mechanisms for interfacing humans with C^3 systems. An interesting discussion of non-cognitive and cognitive human performance factors and tasks is included. 8

Chapters 10 to 12 return to the "traditional" life-cycle based approach. Chapter 10 deals with operation of systems and system management, including hardware, software, communication-channel (e.g., radio-frequency), and facility management. The differences between hardware and software management are particularly well handled; the three-page description of "software management" is a masterpiece in clarity that should become "required reading" for aspiring program managers. 9

Chapter 11 summarizes life-cycle issues for "typical" C^3 systems. After a candid discussion of problems inherent in risk management, it makes the salient point that "the most effective tool for risk management is effective planning." Chapter 12 deals with characterizing and measuring C^3 systems. There are discussions of costs and cost-benefit analyses, of personnel performance, and of system modeling. Case studies in the last chapter address three different types of systems: a strategic missile defense system, a state-wide police/emergency communication system, and a long-distance rail transportation system. Each system description provides the necessary information to permit meaningful approaches to a set of exercises, which are designed to illustrate C^3 system engineering issues. 10

A future edition would benefit from extensions such as: "additional reading" references at the end of each chapter; trade-off analysis needs and tools, at various phases of the system life cycle; discussion of the makeup of system-engineering teams, and of configuration management of C^3 systems; and a more detailed treatise of developmental and operational testing. However, the present edition is well worth its cost to students, engineers, and program managers looking for a concise but thoroughgoing overview of C^3. 11

One final thought: The author has shown with this book that one should not aspire to become a successful systems engineer until one has demonstrated the mental discipline and intellectual capacity to be an expert in at least one engineering specialty. 12

Mr. Doeppner recently retired from the Defense Systems Management College as a Professor of engineering management.

T&E The Key To Successful Acquisition

I am very pleased to endorse the 1989 International Test and Evaluation Association Symposium, whose theme this year is *"Test and Evaluation: The Key to Successful Acquisition."* Certainly 1989 is, and will be, a year of change for the Department of Defense. In this period of decreasing funds and more complex weapons, comprehensive test and evaluation is increasingly more difficult, and critically essential to provide timely information for acquisition decisions. As the Chinese philosopher, Sun Tzu so eloquently stated in the year 300 BC, "The More You Sweat in Peace, the Less You Bleed in War."

The Department of Defense policy is to provide the best weapons and equipment possible in the event of war. The test and evaluation peronnel I have met in my tenure within the armed forces and industry are dedicated to that policy.

I commend this 1989 ITEA Symposium to everyone in the Acquisition and T&E world. There will be participants from the Congress, Department of Defense, industry, foreign test and evaluation acquisition agencies, and a select group of highly experienced T&E professionals for a final wrap-up. I urge you to attend the Symposium in Crystal City, Arlington, Virginia, on 26 to 28 September 1989.

The Honorable John E. Krings
Director, Operational Test and Evaluation
Office of the Secretary of Defense

Early Arrival Registration will be available the evening of September 25, 1989, at the Holiday Inn Crowne Plaza from 6 p.m. until 9 p.m., pending available attendance openings. Attendance is limited to 500 people. Cut-off date for cancellations is Monday, September 18, 1989. There will be no refunds after that date.

NOTE: Registration fees of $250.00 and $290.00 include 1 banquet, 2 luncheons, 1 reception and 1 proceedings package. Additional tickets for non-member registered guests are priced as shown. Persons attending 1 session or 1 day only who wish to attend either a luncheon, the banquet or the reception need to purchase those tickets at the prices indicated. Industry non-member fee includes $40.00 ITEA membership fee.

Hotel accommodations can be arranged by calling the Holiday Inn Crowne Plaza at 1-800-848-7000.

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ISSN 0199-7114

U.S. GOVERNMENT PRINTING OFFICE: 1989-242-469/00004